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SIZE ANALYSIS OF SAND SAMPLES FROM SOUTHERN NEW JERSEY BEACHES.(U)
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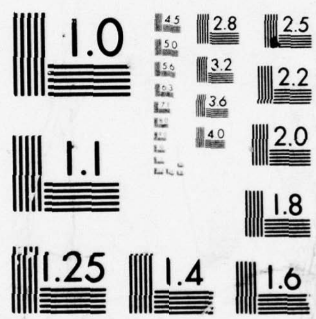

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Size Analysis of Sand Samples from Southern New Jersey Beaches

by

Michael D. Ramsey and Cyril J. Galvin, Jr.

MISCELLANEOUS REPORT NO. 77-3

MARCH 1977

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U.S. ARMY, CORPS OF ENGINEERS

COASTAL ENGINEERING RESEARCH CENTER

Kingman Building

Fort Belvoir, Va. 22060

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The size of sand on Atlantic coast beaches of southern New Jersey was studied by analyzing 788 sand samples. In north-to-south order, the samples were collected at Island Beach, Long Beach Island, Brigantine, Atlantic City, and Ludlam Island. Sand size generally decreased from north to south, with size at the two northernmost sites noticeably coarser on the average than the size at the three southern sites. Results from Long Beach Island, Atlantic City, and Ludlam Island, where most of the data were collected,
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indicate that size, averaged by beach, decreases from 0.33 millimeter at Long Beach Island in the north, through 0.27 millimeter at Atlantic City, to 0.23 millimeter at Ludlam Island in the south. Size, averaged by profile line, varies from 0.34 millimeter at a profile on the northern half of Long Beach Island, to 0.20 millimeter at a profile in the middle of Ludlam Island. Size also varies with position across the profile from low tide terrace to landward edge of berm, tending to decrease landward across the average of three profiles on Atlantic City and three profiles on Ludlam Island, but tending to increase landward across the average of four profile lines on Long Beach Island. Maximum variation at one beach, averaged by position on profile, occurs at Long Beach Island where the average size increased from 0.28 millimeter on the low tide terrace to 0.36 millimeter on the berm. Size variation by month suggests a tendency for sand to be finer during late summer and early fall, but data do not permit identification of a consistent annual cycle. Maximum variation at one beach over the entire sampling period occurred at Ludlam Island, where size increased from 0.19 millimeter in October 1968 to 0.27 millimeter in March 1969. When classified by month or by position on profile, size at Atlantic City tends to increase when size increases at Ludlam Island, 19 miles to the south, and to decrease when size increases at Long Beach Island, 23 miles to the north. The results in this report provide site-specific engineering data for New Jersey beaches, and suggest ways to improve beach fills at these sites.

PREFACE

This report is published to provide coastal engineers with data on median sand size from Atlantic coast beaches of New Jersey. Sand is the most common material on beaches throughout the United States, and median size is the standard characteristic used to describe beach sand for engineering purposes. The work was carried out under the Beach Evaluation Program of the U.S. Army Coastal Engineering Research Center (CERC).

The report was prepared by Michael D. Ramsey, a former student trainee, and Cyril J. Galvin, Jr., Chief, Coastal Processes Branch, under the general supervision of R.P. Savage, Chief, Research Division, CERC.

The authors acknowledge the assistance of the surveyors from the U.S. Army Engineer District, Philadelphia, who collected the samples analyzed. Dr. D.B. Duane, C. Judge, M. Koenig, J.C. Muzik, and P. Turner provided the Rapid Sediment Analyzer (RSA) analyses. A.E. DeWall, W.N. Seelig, L.W. Tenney, M.W. Leffler, and B.H. Gwinnup assisted in the data analyses and report preparation.

Comments on this publication are invited.

Approved for publication in accordance with Public Law 166, 79th Congress, approved 31 July 1945, as supplemented by Public Law 172, 88th Congress, approved 7 November 1963.

JOHN H. COUSINS
Colonel, Corps of Engineers
Commander and Director

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CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U.S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	by	To obtain
inches	25.4	millimeters
	2.54	centimeters
square inches	6.452	square centimeters
cubic inches	16.39	cubic centimeters
feet	30.48	centimeters
	0.3048	meters
square feet	0.0929	square meters
cubic feet	0.0283	cubic meters
yards	0.9144	meters
square yards	0.836	square meters
cubic yards	0.7646	cubic meters
miles	1.6093	kilometers
square miles	259.0	hectares
knots	1.8532	kilometers per hour
acres	0.4047	hectares
foot-pounds	1.3558	newton meters
millibars	1.0197×10^{-3}	kilograms per square centimeter
ounces	28.35	grams
pounds	453.6	grams
	0.4536	kilograms
ton, long	1.0160	metric tons
ton, short	0.9072	metric tons
degrees (angle)	0.1745	radians
Fahrenheit degrees	5/9	Celsius degrees or Kelvins[1]

[1] To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use formula: $C = (5/9)(F - 32)$. To obtain Kelvin (K) readings, use formula: $K = (5/9)(F - 32) + 273.15$.

SIZE ANALYSIS OF SAND SAMPLES FROM SOUTHERN NEW JERSEY BEACHES

by
Michael D. Ramsey and *Cyril J. Galvin, Jr.*

I. INTRODUCTION

1. Purpose.

This report presents data on the spatial and temporal variations in mean sand size along and across Atlantic coast beaches in southern New Jersey. The report documents sand-size characteristics of three New Jersey beaches (Long Beach Island, Atlantic City, and Ludlam Island) which will be subjects of detailed locality reports for the U.S. Army Coastal Engineering Research Center (CERC) Beach Evaluation Program (BEP). However, the analysis of the data in this report serves at least three other coastal engineering uses:

(a) In showing the naturally occurring sand-size variation by profile location, position on profile, and month, the data help estimate how representative are the sand samples usually obtained for coastal engineering studies.

(b) The data on variation across the profile with the month of the year can help in the design of beach fills for these localities.

(c) The spatial and temporal distribution of sand sizes on this significant section of the New Jersey coast can help in interpreting the long-term history of coastal processes acting on this shore.

2. Background.

The beaches sampled for this study include (from north to south): Island Beach, Long Beach Island, Brigantine, Atlantic City, and Ludlam Island, a shoreline distance of about 60 miles (100 kilometers) from the northernmost sampling locality on Island Beach to the southernmost sampling locality on Ludlam Island (Fig. 1). The positions of the sampled profile lines are in Figures 2 to 7.

Two sets of samples are involved: Sample set A, 469 samples from Long Beach Island, Atlantic City, and Ludlam Island collected between January 1968 and March 1969; and sample set B, 319 samples from all five localities, mostly collected in 1971, 1972, and 1973. Sample set B was collected to answer questions which developed from an analysis of sample set A (Ramsey and Galvin, 1971, pp. 46 and 47).

Most of the sand samples were collected by personnel of the U.S. Army Engineer District, Philadelphia, as part of the beach surveys for the BEP.

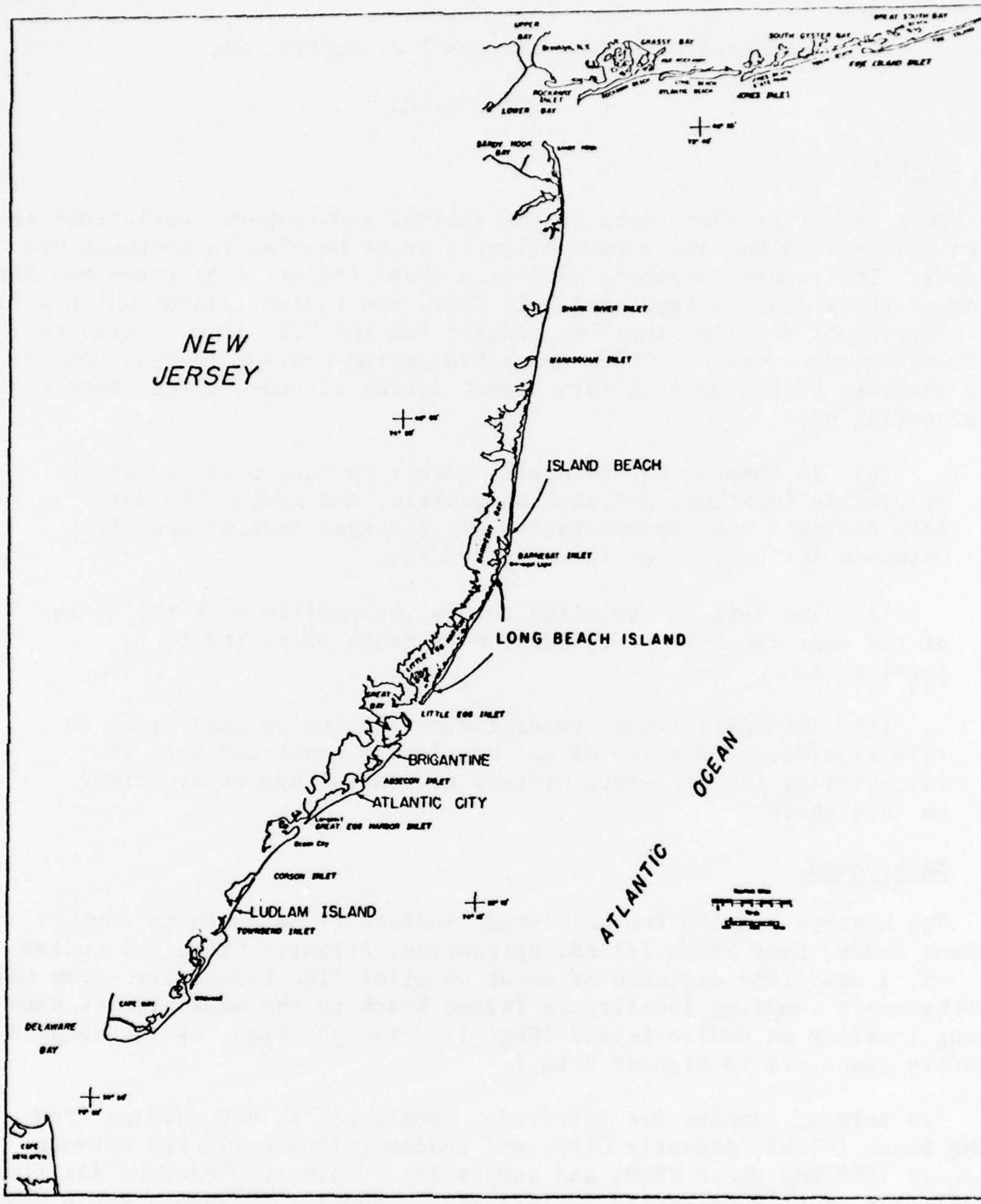

Figure 1. Sand collection localities.

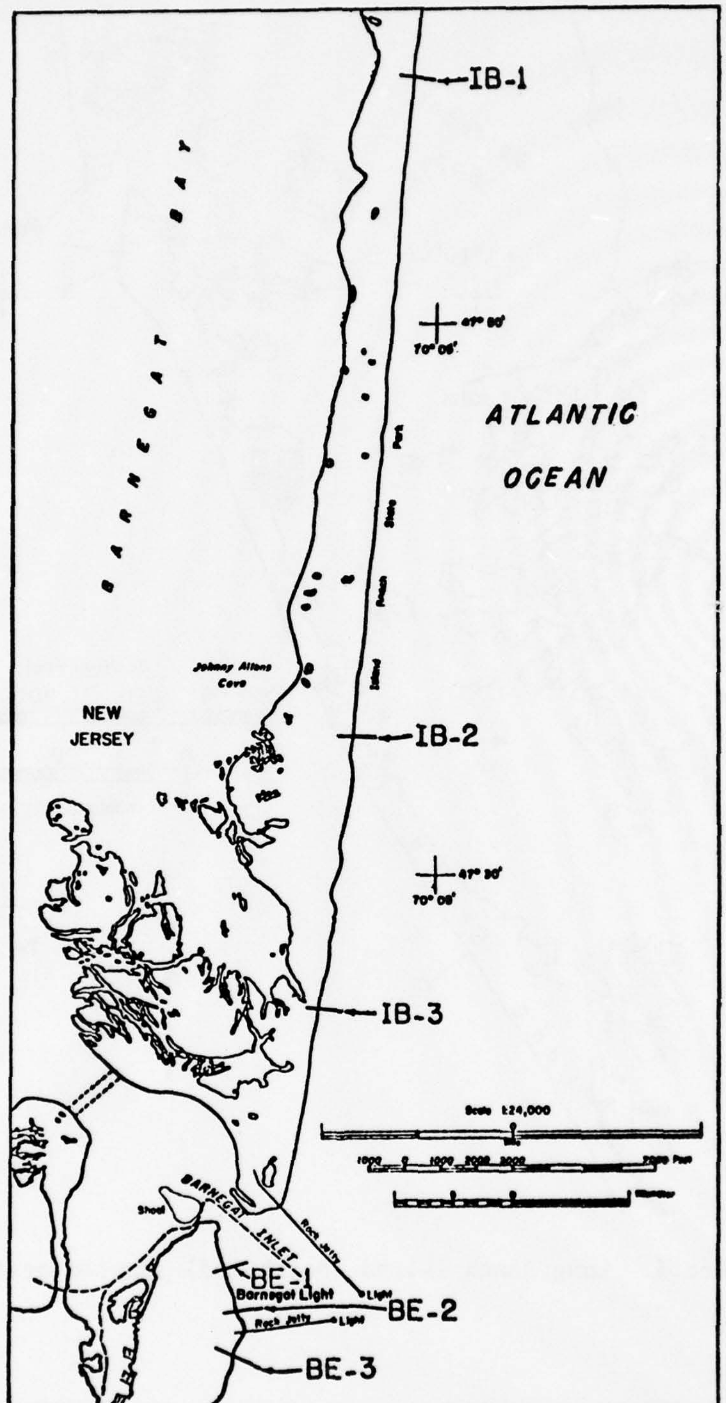

Figure 2. Island Beach sampled profile lines.

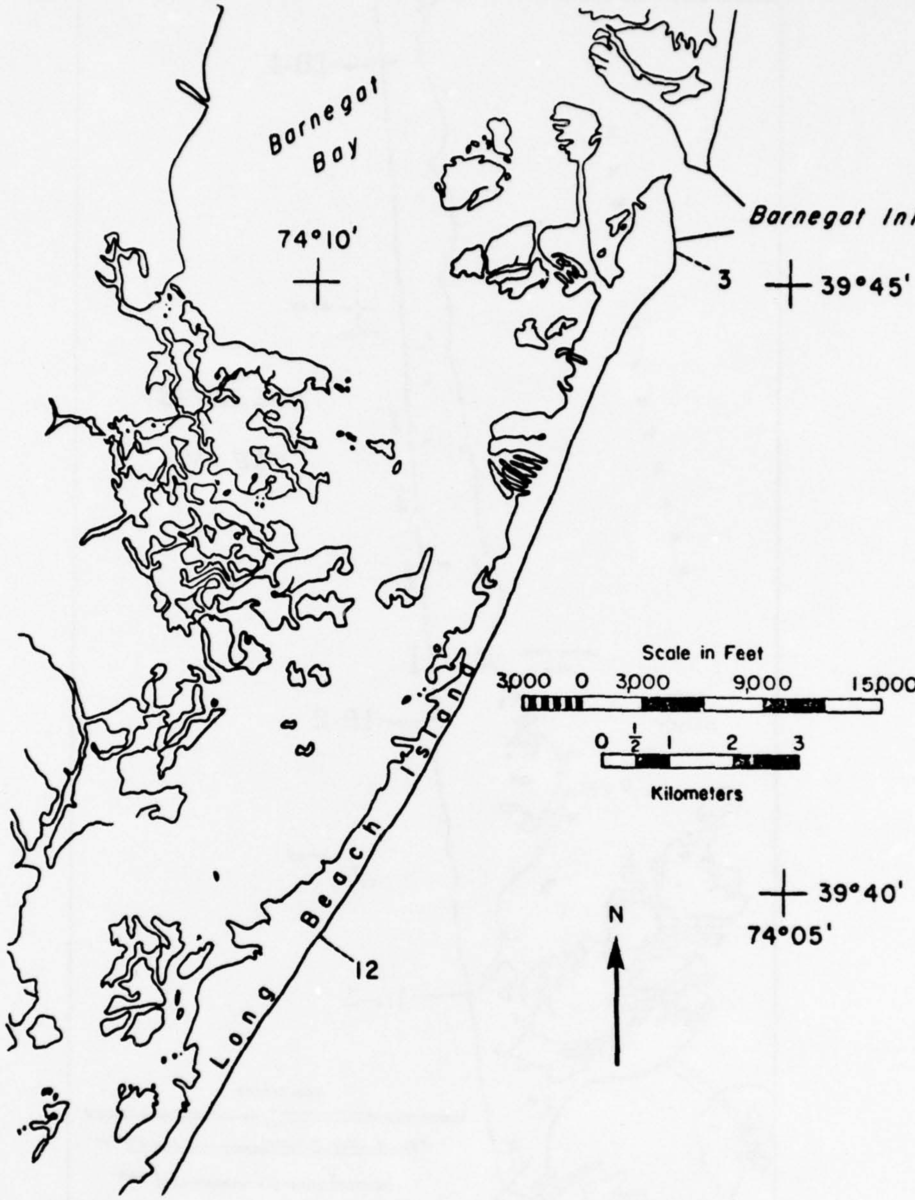

Figure 3. Long Beach Island (north end) sampled profile lines.

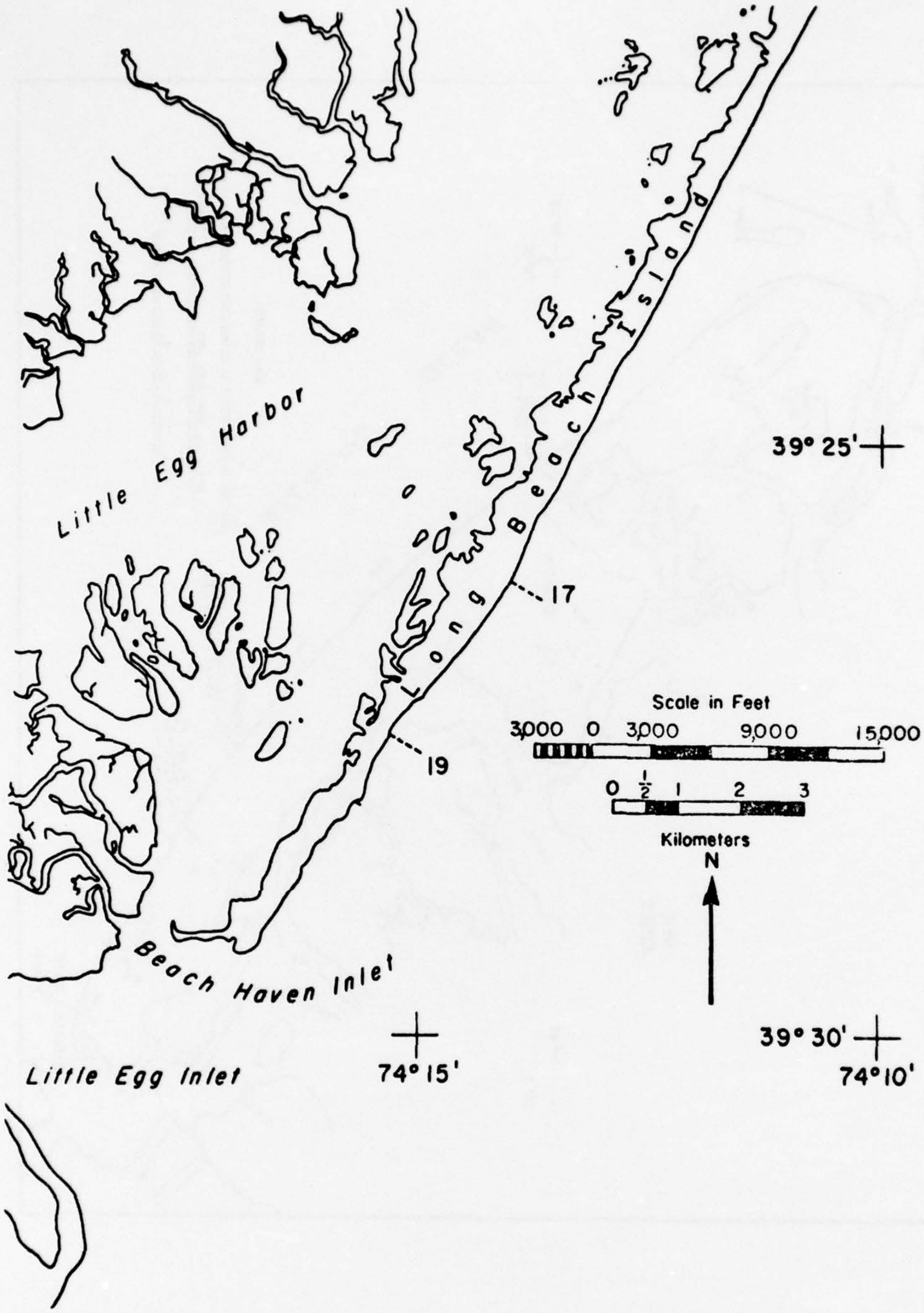

Figure 4. Long Beach Island (south end) sampled profile lines.

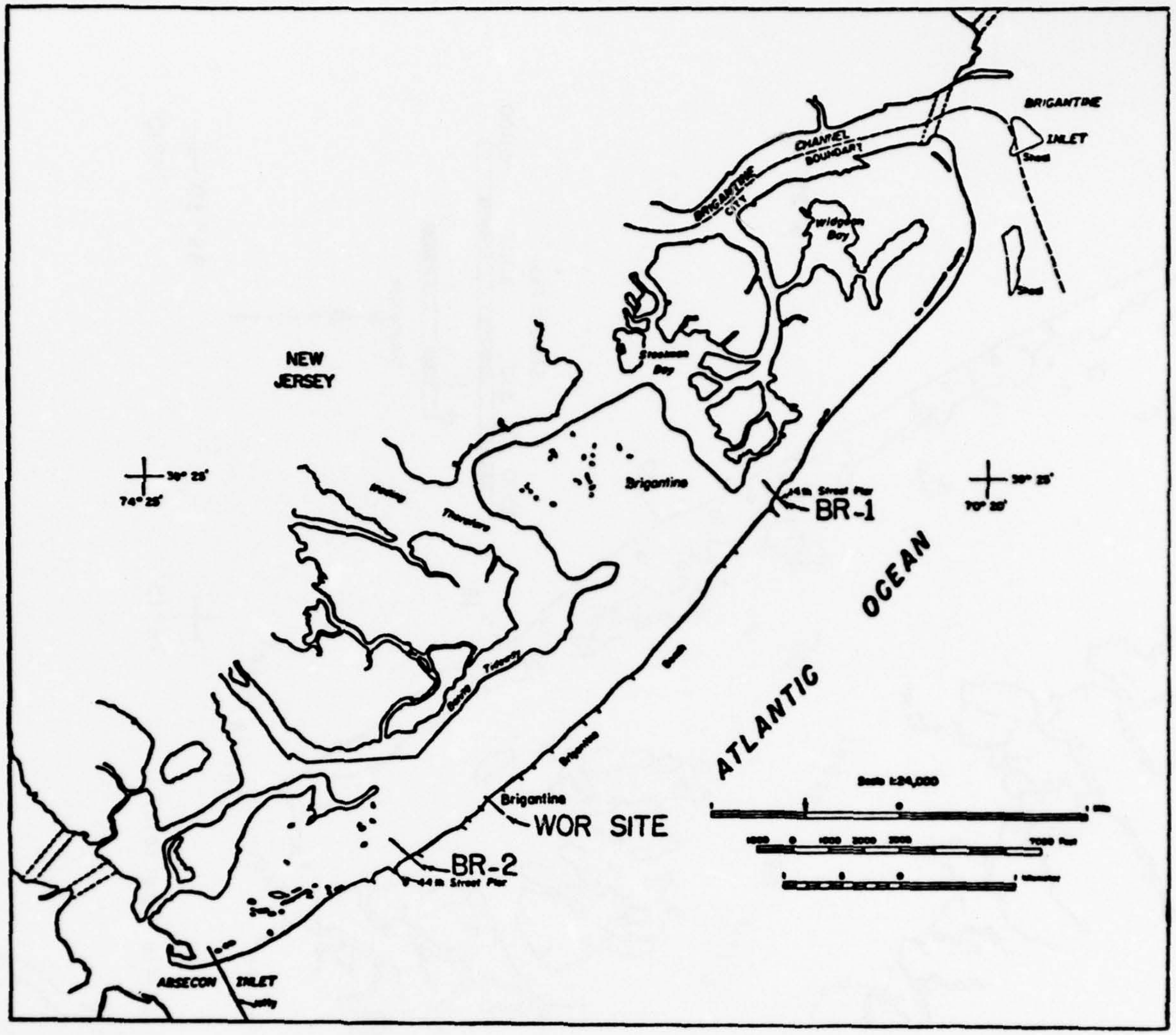

Figure 5. Brigantine sampled profile lines.

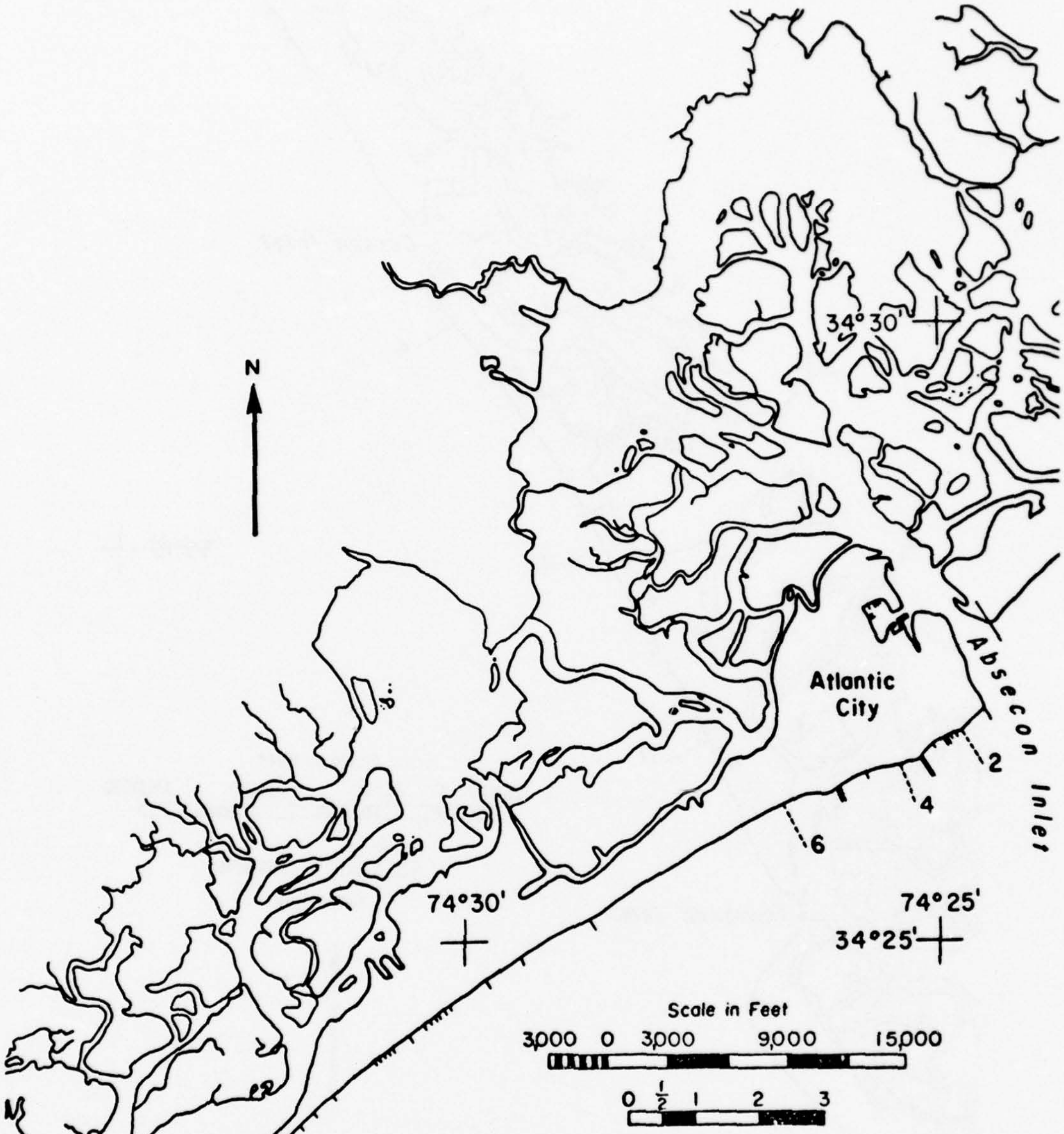

Figure 6. Atlantic City sampled profile lines.

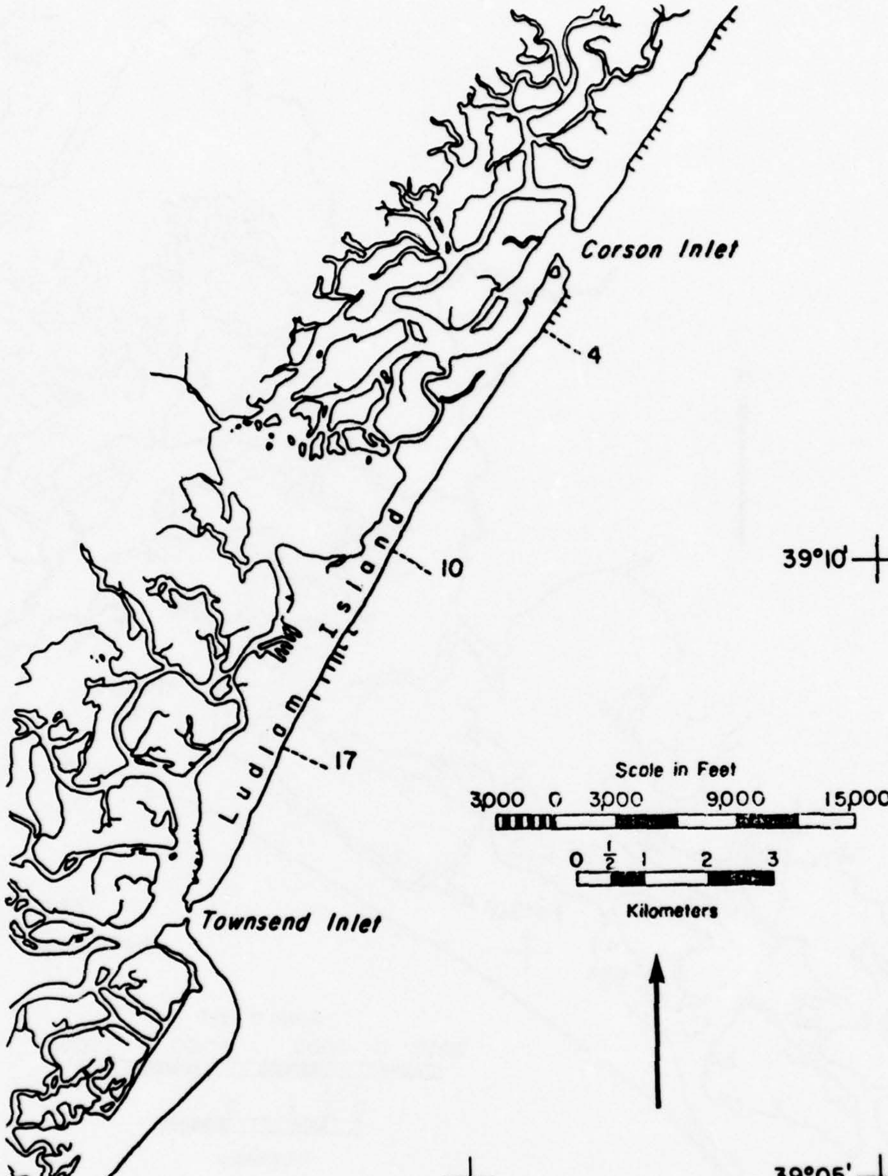

Figure 7. Ludlam Island sampled profile lines.

The BEP is an extended study of the protective capacity of selected beaches, initiated after the extreme destruction wrought by the East Coast Storm of March 1962. BEP reports for Ludlam Island and Long Beach Island are in preparation; the effects of the December 1970 storm on these beaches are analyzed in DeWall, Pritchett, and Galvin (1977). The Atlantic City beaches were reported in Everts, DeWall, and Czerniak, (1975).

Ramsey and Galvin (1971) contains detailed descriptions of the methods of analyses of sample set A as well as appendixes with the basic data pertaining to sample set A.

3. Previous Work.

MacCarthy (1931) analyzed samples collected by the U.S. Coast Guard from three New Jersey beaches; McMaster (1954) collected and analyzed 34 samples from the same three beaches. Both analyses showed that sand size decreases to the south along this section of the New Jersey coast. The results of both MacCarthy and McMaster are compared with the results of this study in a later section.

Settling velocities of beach and dune sands from Avalon (just south of Ludlam Island) and Beach Haven (Long Beach Island), and from points between these two locations, have been compared by Hand (1967), but without discussing mean size.

II. PROCEDURE

1. Collecting and Cataloging Samples.

The analysis procedure for sample set A is outlined on the flow chart in Figure 8. The procedure is also detailed in Ramsey and Galvin (1971), which includes complete appendixes. Samples were obtained by surveyors from surveyed locations on the profile while the profile was being surveyed, so the position and elevation of these samples are accurately known. At CERC, the latitude and longitude of each sample station were determined to the nearest 0.01 minute. These locations are listed in Appendix A of Ramsey and Galvin (1971).

The surveyors collected grab samples by taking the top few inches of sand with a spade. No effort was made to make the sampling technique more precise than this.

Appendix B of Ramsey and Galvin (1971) lists all analyzed samples by consecutive number. (Note that the "sample number" is the number given to the samples by the surveyors who collected it; the "consecutive number" is the number given to the sample by the personnel at CERC who analyzed it.) The depth code used to classify the elevation of the samples was determined from a computer printout of the profile survey (Fig. 9). The mean tidal range of 4.1 feet for each locality was taken from tide tables

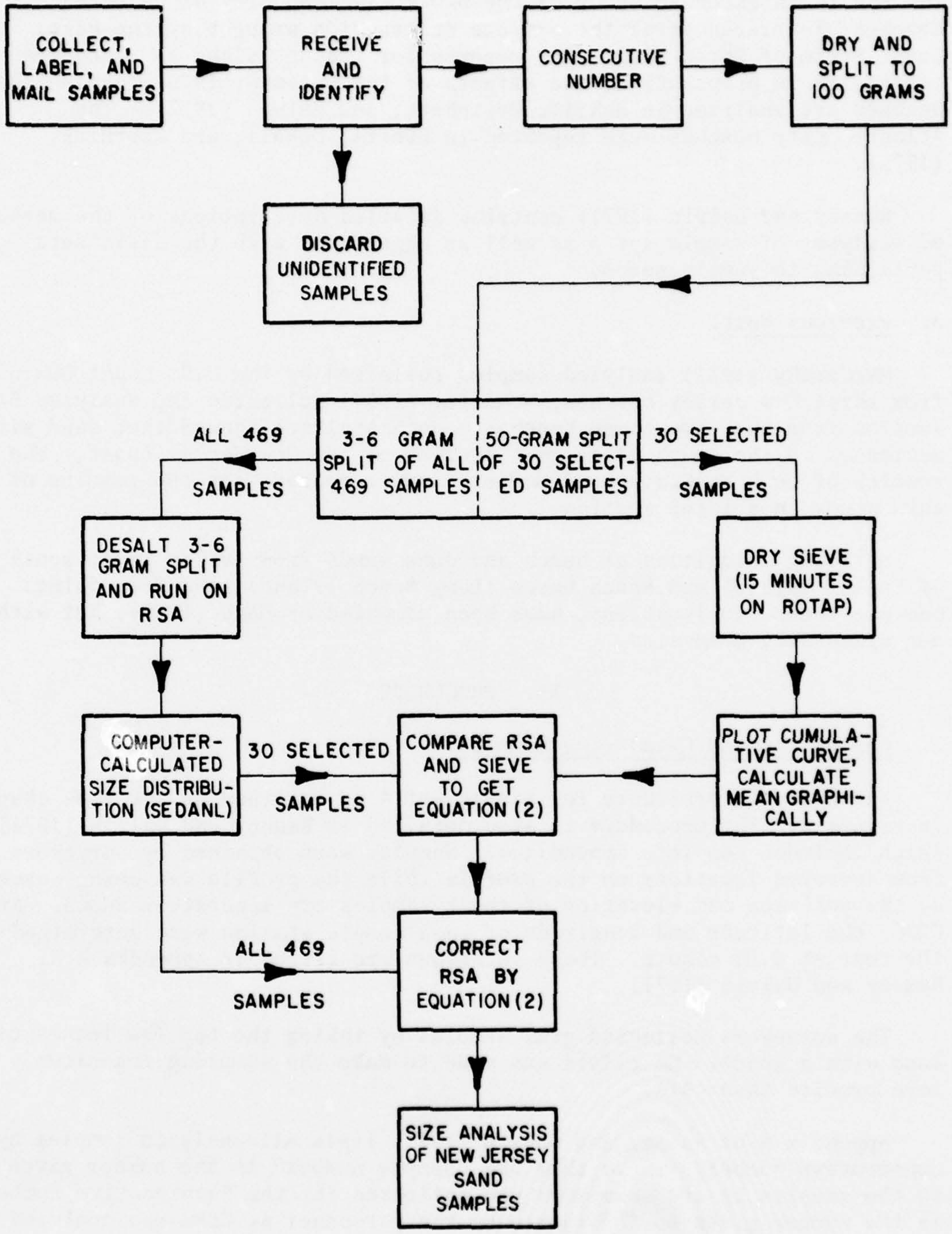

Figure 8. Procedure for analysis of sample set A.

LOC	PRO	SURVEY	SHEETS	DATE	HOUR	DATUM	METHOD	CHANGE IN BM	REMARKS
10	04	07	2	29JAN69	9	MSL	HAND	NO	NO

DIST	ELEV
0.	10.7
50.	10.4
100.	10.0
150.	9.3
200.	8.9
250.	7.4
300.	4.7
350.	2.8
400.	.8
450.	-.1
500.	-1.4
550.	-2.1
600.	-3.1

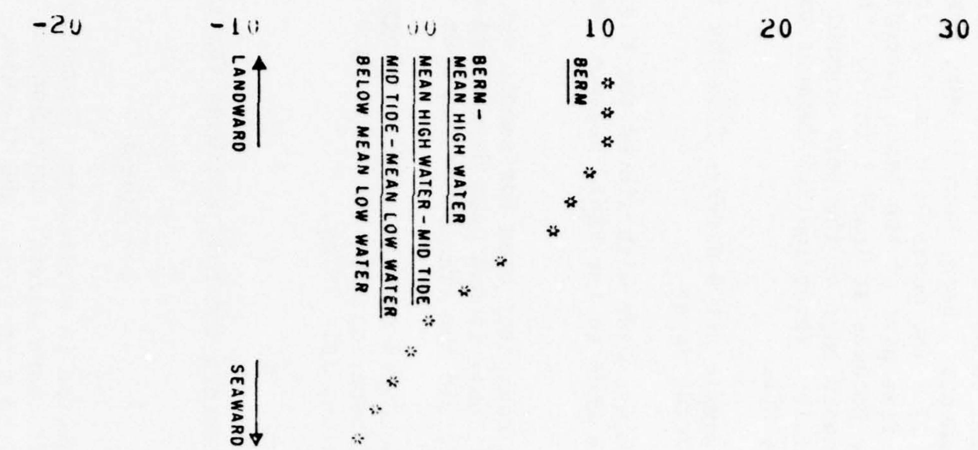

Figure 9. Computer printout of profile with depth code nomenclature.

(National Oceanic and Atmospheric Administration, 1973). Mean high water (MHW) was assumed to be 2.05 feet above mean sea level (MSL) and mean low water (MLW) was assumed to be -2.05 feet MSL. The beach profile was then divided into five segments: Berm, berm to MHW, MHW to MSL, MSL to MLW, and below MLW (Table 1). (No dunes were sampled in this study.) The berm segment was the flat part of the beach extending seaward to the point where the beach slope becomes at least 1 in 50. The berm to MHW segment extended from the seaward edge of the berm segment to a point 2.05 feet above MSL on the profile. The below MLW segment extended seaward from a point 2.05 feet below MSL.

The analysis of sample set B differs from the flow chart (Fig. 8) in the following significant ways:

(a) No check was made with sieves for the sample set B and no adjustment was made to the Rapid Sediment Analyzer (RSA) output.

(b) The RSA equipment used for sample set B was the same as for sample set A, only it had been dismantled and rebuilt in another location, and the transducer had been changed.

(c) The procedures and the computer program used to produce RSA analyses had been improved (C. Judge, geologist, CERC, personal communication, July 1976).

2. Units.

Two units (millimeters and phi) are used for sand size. The phi unit is defined by:

$$\phi = -\log_2 D \tag{1}$$

where D is the diameter in millimeters (Krumbein, 1939, p. 566). In this report, phi units have several conveniences, particularly in relating mean sizes obtained from sieves and the RSA. However, the engineer unfamiliar with phi units must remember three characteristics of these units (U.S. Army, Corps of Engineers, Coastal Engineering Research Center, 1975, p. 4-15): (a) Sand diameter increases as phi size decreases; (b) the phi unit is dimensionless, so differences in sand size in phi units are difficult to interpret physically; and (c) averages of sand size in phi units are the geometrical mean of the sample means, rather than the arithmetic mean. All averages in this paper are averages of sizes in phi units.

3. RSA Analyses of the Samples.

The RSA is modeled after the settling tube at Woods Hole Oceanographic Institution, Woods Hole, Massachusetts (Zeigler, Whitney, and Hayes, 1960). It uses the change in the pressure differential between two water-filled

Table 1. Dry sieve and RSA means of sample set A used to obtain equation 2.

Sample	Dry sieve		RSA	
(No.)	(phi)	(mm)	(phi)	(mm)
19	1.69	0.3099	1.33	0.398
29	2.16	0.2238	1.89	0.270
39	1.46	0.3635	1.14	0.454
49	1.98	0.2535	1.58	0.335
59[1]	0.69	0.6199	1.07	0.476
70	1.54	0.3439	1.27	0.415
80	2.12	0.2380	1.80	0.287
93	2.46	0.1817	1.74	0.299
97	2.43	0.1856	1.94	0.261
107	1.59	0.3322	1.21	0.432
117	1.81	0.2852	1.33	0.398
126	1.49	0.3415	1.12	0.460
135	2.18	0.2207	1.84	0.279
145	2.80	0.1436	1.88	0.272
155	1.78	0.2912	1.57	0.337
165	1.66	0.3164	1.35	0.392
175	2.17	0.2222	1.86	0.276
185	2.23	0.2132	1.83	0.281
198	1.57	0.3368	1.20	0.435
209	1.40	0.3789	1.11	0.463
211	2.11	0.2316	1.83	0.281
220	1.62	0.3231	1.36	0.390
222	1.47	0.3610	1.21	0.432
234	2.14	0.2269	1.83	0.281
247	1.32	0.4005	0.97	0.511
252	1.62	0.3253	1.26	0.418
271	1.24	0.4234	0.95	0.518
284	1.44	0.3686	1.47	0.361
287	2.42	0.1869	2.14	0.227
296	1.63	0.3231	1.29	0.409

[1]Cumulative curve for this sample was extrapolated to obtain value for the 10th percentile.

tubes, as a sand sample falls through one of the tubes, to determine the fall velocities of the particles. A computer program, SEDANL, then relates fall velocity to hydraulic diameter, using tables which were empirically determined at the Woods Hole Oceanographic Institution (Zeigler and Gill, 1959). The hydraulic diameter of a particle is defined as the diameter of a quartz sphere having the same fall velocity as the fall velocity of the measured particle.

Figure 10 is an example of a SEDANL printout, using data from sample 93. The "cumulative percent" column indicates the percentages of sand grains which are coarser than the indicated size. The "frequency percent" column represents a distribution of particle sizes falling between the indicated size and the next coarser size. Thus, 46.33 percent adjacent to 2.0 phi in the frequency percent column indicates that 46.33 percent of the sample was between 2.0 and 1.5 phi.

Although the SEDANL output (Fig. 10) lists results to the nearest 0.01 percent, the actual accuracy is unknown. SEDANL uses the fall velocity of an equivalent quartz sphere to determine the diameter of particles, but possible effects of particle shape, density, and concentration on fall velocity, suggest that the actual physical size of the particles may differ from that indicated.

4. Sieve Analysis of the Samples.

Eleven sieves with screen openings, in millimeters (phi in parenthesis), of 2.00 (-1.00), 1.41 (-0.50), 1.00 (0.00), 0.707 (0.50), 0.500 (1.00), 0.356 (1.50), 0.250 (2.00), 0.177 (2.50), 0.125 (3.00), 0.088 (3.50), and 0.062 (4.00) were used in the sample analysis. The weight of sand collected on each sieve was entered on the sediment analysis form (Fig. 11) and percentages computed for plotting on cumulative curves (Fig. 12) from which sample mean sizes were graphically computed. For ease in following through this analysis, data from sample 93 have been used as examples on the SEDANL output (Fig. 10), the sieve analysis (Fig. 11), and the computation of the dry-sieve mean (Fig. 12).

To some extent, size depends on the definition used. The sieve diameter of a particle is sometimes defined (Kennedy and Koh, 1961, p. 4233) as the geometric mean of the sieve openings in the last sieve through which the particle passed and the sieve openings of the sieve on which it is retained. Usually, the size of each fraction retained on a sieve is defined as equal to the size of the sieve openings on which it rests, and this retaining sieve definition is used in this report. This is consistent with the RSA output, since the SEDANL program interprets settling velocity in size classes equivalent to the retaining sieve definitions, assuming the particles are quartz spheres. This difference between the geometric and retaining sieve definitions of size is equal to one-half the size difference between neighboring sieves. For the 0.5-phi interval sieves in this report, the retaining sieve definition gives sizes 0.25 phi smaller than the geometric mean definition (Fig. 13). Thus, sand estimated

REFERENCE NUMBER	CONSECUTIVE NUMBER	MARSDEN SQUARE	1 DG. SQUARE	DEPTH ZONE	CORE TOP	CORE BOTTOM(CM)	ANALYSIS CODE
536	93	116	94	2	0	0	1

AT CTY,BE- D:STA-150',SN--4,5 FEB69,3.6/G

PHI SIZE	MM. SIZE	FREQUENCY PERCENT	CUMULATIVE PERCENT
1.00	.500	.00	.00
1.50	.354	31.44	31.44
2.00	.250	46.33	77.77
2.50	.177	20.21	97.98
3.00	.125	2.02	100.00
3.50	.088	.00	100.00
4.00	.062	.00	100.00
.LT. 4.00	.062	.00	100.00

STATISTICAL PARAMETERS	PHI	MM.
MEDIAN	1.68	.313
MEAN	1.74	.300
STANDARD DEVIATION	.33	1.260
SKEWNESS	.67	
KURTOSIS	2.58	

Figure 10. SEDANL output for sample 93.

Analysis No. ....

BEACH EROSION BOARD SEDIMENT ANALYSIS

Field sample no. CN: 93 Collected by .... Date 5 FEB 69
Project BEP
Location ABSECON ISLAND, BE-D, 150'
Remarks ....

SIEVE ANALYSIS OF SAND

Weight of sample 54.08 gr. Analyzed by MDR Date 29 SEP 69

Screen Opening MM.	U. S. Mesh Number	Retained on sieves Grams	Retained on sieves Per Cent	Cumulative Retained on sieves Grams	Cumulative Retained on sieves Per Cent	Cumulative Per cent Passing
26.670	-					
19.100	-					
9.520	-					
6.350	-					
4.760	4					
4.00	5					
3.360	6					
2.83	7					
2.38	8					
2.00	10	.04	.07	.04	.07	99.93
1.41	14	.00	.00	.04	.07	99.93
1.00	18	.01	.02	.05	.09	99.91
707μ	25	.05	.09	.10	.18	99.82
500μ	35	.08	.14	.18	.33	99.68
354μ	45	.62	1.15	.80	1.48	98.53
250μ	60	8.31	15.37	9.11	16.85	83.16
177μ	80	20.02	37.01	29.13	53.86	46.15
125μ	120	17.82	32.97	46.96	86.82	13.18
88μ	170	6.31	11.67	53.27	98.49	1.51
0.062	230	.50	.92	53.77	99.41	.54
0.000	Pan					
Totals		53.77	99.41			
Gain or loss		.31	.59			

STATISTICAL VALUES
Median diameter .... mm.
Geometric mean diam. .... mm.
Phi standard deviation ....
Effective size .... mm.
Uniformity coefficient ....
Abrams fineness modulus ....
D 25% .... mm. D 75% .... mm.
Sorting coefficient ....
Sieving time .... min.
Computed by .... Date ....

SPECIFIC GRAVITY
Weight of flask .... gr.
Wt. of flask & sand .... gr.
Weight of sand .... gr.
Wt. flask, sand & water .... gr.
Wt. (volume) of water .... gr. (cc.)
Volume of sand .... cc.
Temperature of water .... °C
Absolute specific gravity .... gr./cc.
Dry specific gravity .... gr./cc.
Analyzed by .... Date ....

Figure 11. Sediment analysis form for dry-sieving sample 93.

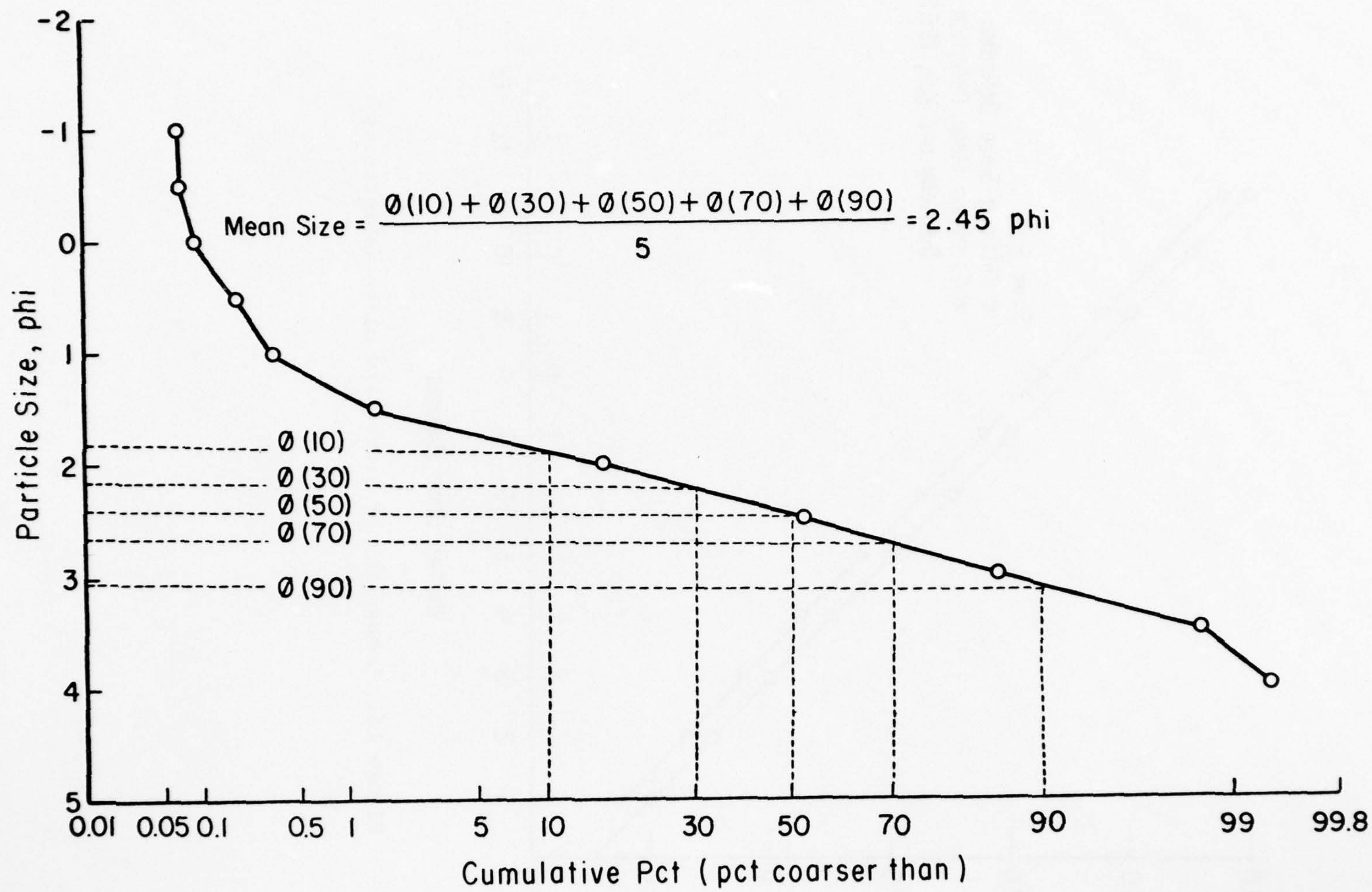

Figure 12. Graphical computations of mean size for sample 93.

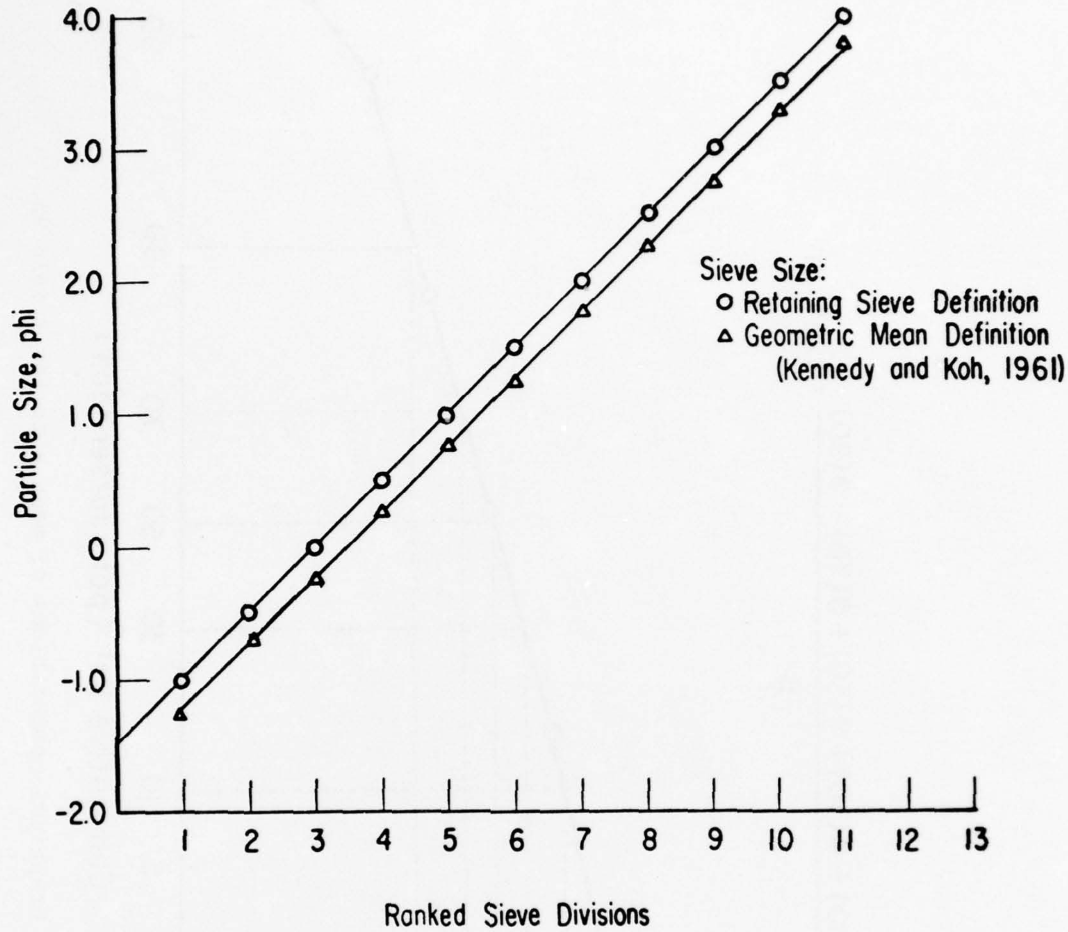

Figure 13. Comparison of sieve-size class definitions.

to be 0.30 millimeter by the retaining sieve definition would be about 0.35 millimeter by the geometric mean definition.

5. Comparison of RSA and Sieve Analyses.

The mean RSA and dry sieve sizes of the 30 samples from sample set A processed by both methods are listed in Table 1 and compared in Figure 14. There is a well-defined shift to the right in Figure 14 which shows that the processed RSA data usually indicate coarser means than those calculated from dry sieve data. A visual fit line (solid line) drawn through the data has an average shift of 0.33 phi. Therefore, RSA means of all samples in sample set A were corrected using the following formula:

$$\text{SAMPLE MEAN} = \text{RSA MEAN} + 0.33\ \text{PHI} \quad . \tag{2}$$

Hereafter, for data in sample set A, the term, "sample mean," is defined by this equation. Sample means allow a reasonable comparison of CERC's settling tube data to McMaster's (1954) sieve data. However, since sample mean and RSA mean differ by only a constant additive factor when working in phi units, relative changes will be the same whether sample means or RSA means are used; i.e., the trends which show up in Figures 15, 16, 17, and 18 are really trends in the fall velocities of the particles making up the particular samples and not necessarily trends in the geometric size of the particles.

The sample correlation coefficient (Natrella, 1966) for Figure 14 was 0.90. Assuming a perfectly random selection procedure was used to choose the 30 samples, there is a 95-percent probability that the correlation coefficient for the entire population (469 samples) is between 0.81 and 0.95. The sample correlation coefficient improves to 0.92 if the extrapolated sample (consecutive number 59) is ignored, giving a 95-percent confidence interval of 0.85 and 0.96.

The solid curve in Figure 14 was visually fit to the data. Linear regression yields the equation:

$$y = 0.68\ X + 0.25 \tag{3}$$

for all data points and

$$y = 0.84\ X - 0.06 \quad , \tag{4}$$

when consecutive number 59 was ignored. Confidence intervals (Guttman and Wilks, 1965) for equation (4) were computed to be:

$$[0.84 \pm 0.24]_{95\%} \text{ and } [0.84 \pm 0.20]_{90\%}$$

for the slope and

$$[-0.06 \pm 0.22]_{95\%} \text{ and } [-0.06 \pm 0.18]_{90\%}$$

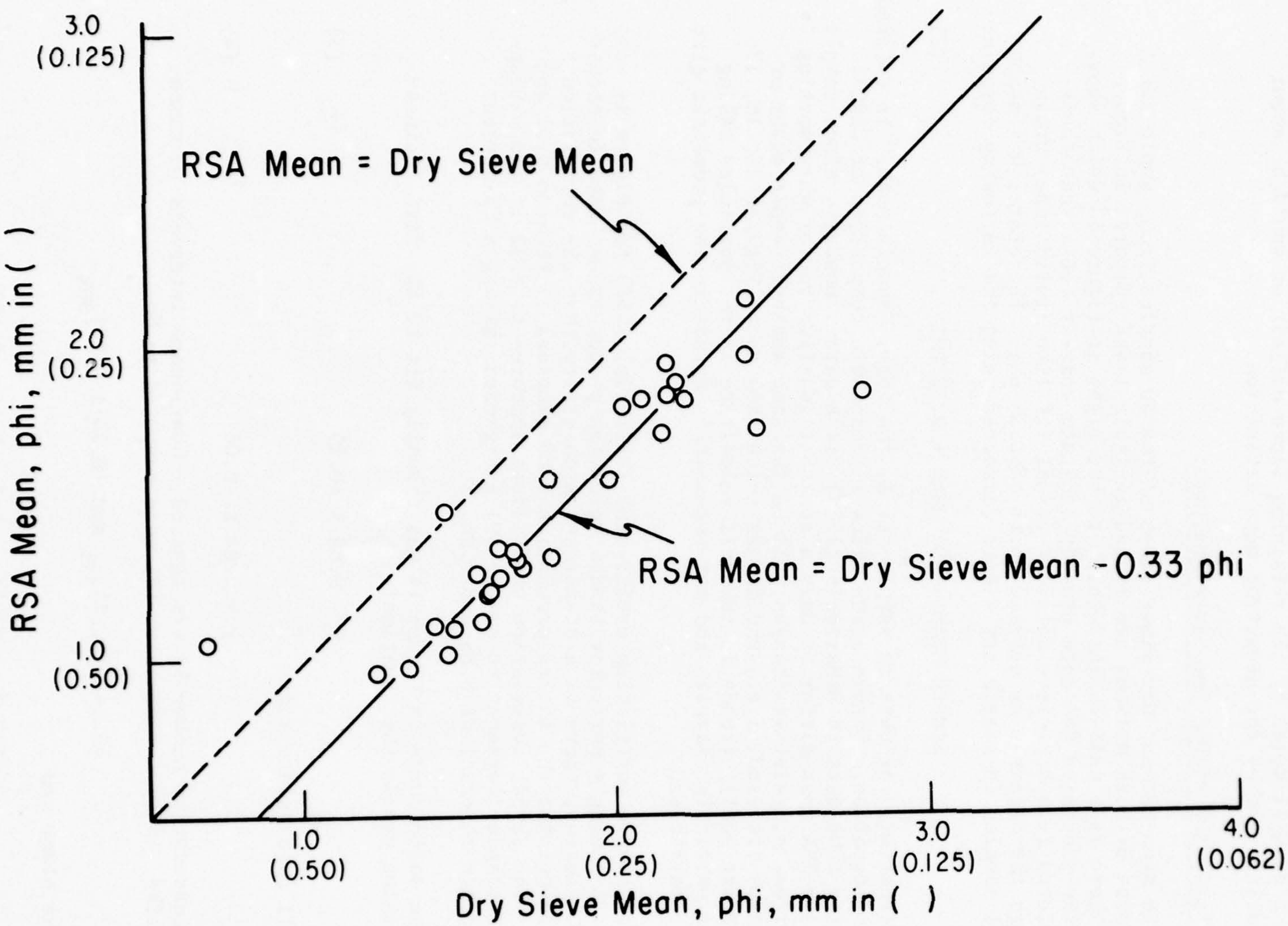

Figure 14. Relation between RSA and dry sieve means of 30 southern New Jersey beach samples (sample set A).

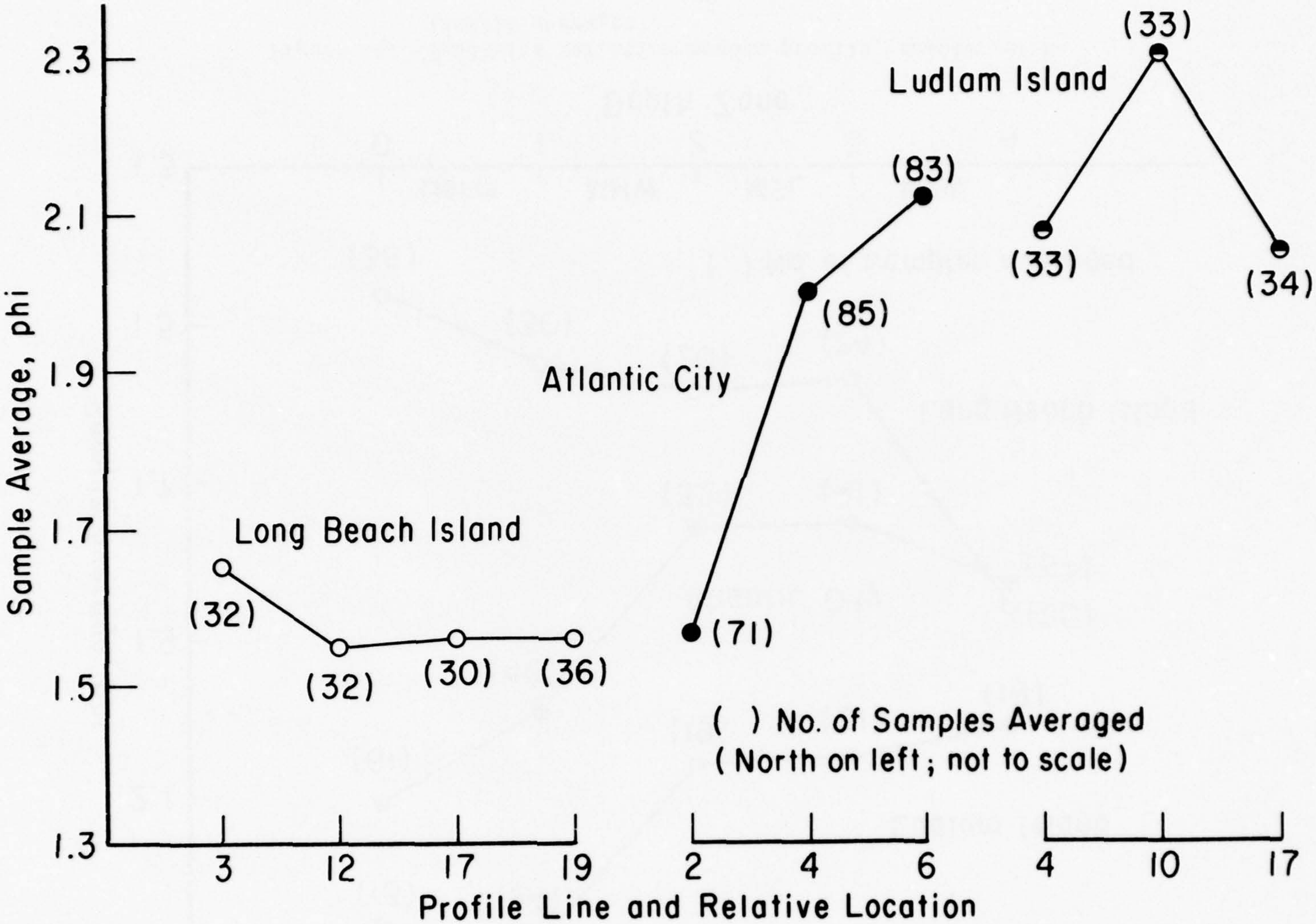

Figure 15. Southward decrease in sand size on three New Jersey beaches, sample set A.

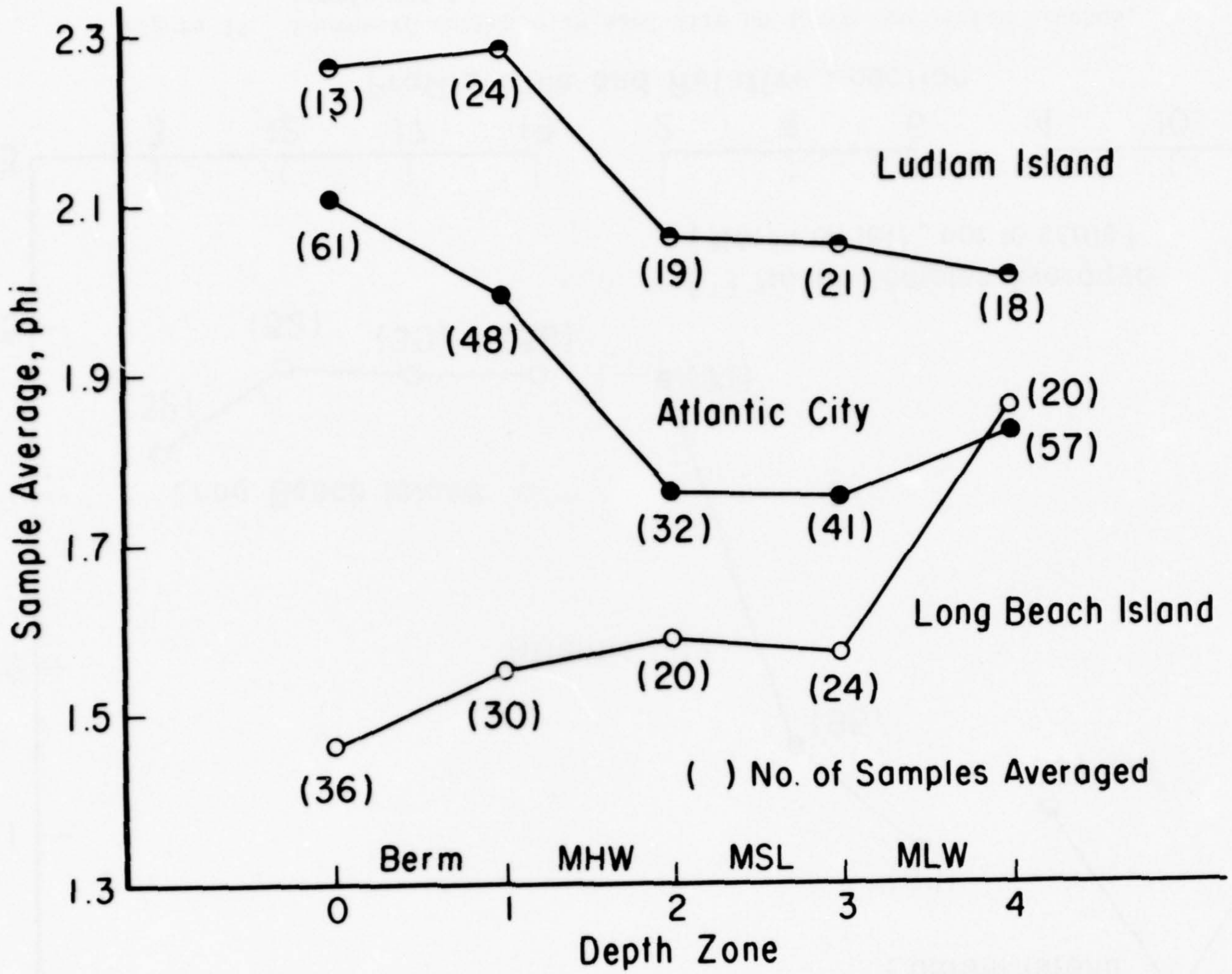

Figure 16. Sand-size variation across profile, sample set A (sample averages).

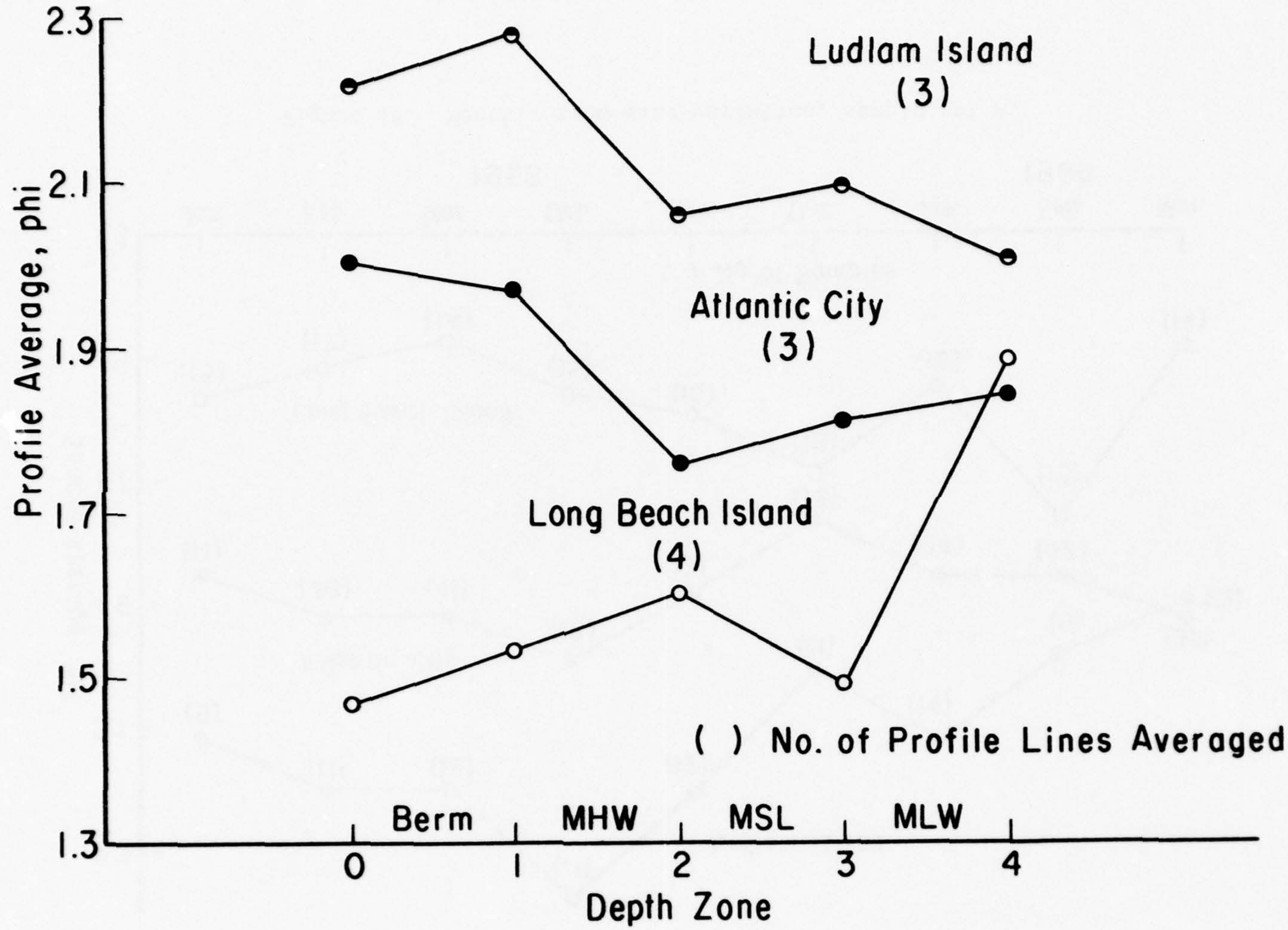

Figure 17. Sand-size variation across profile, sample set A (profile averages).

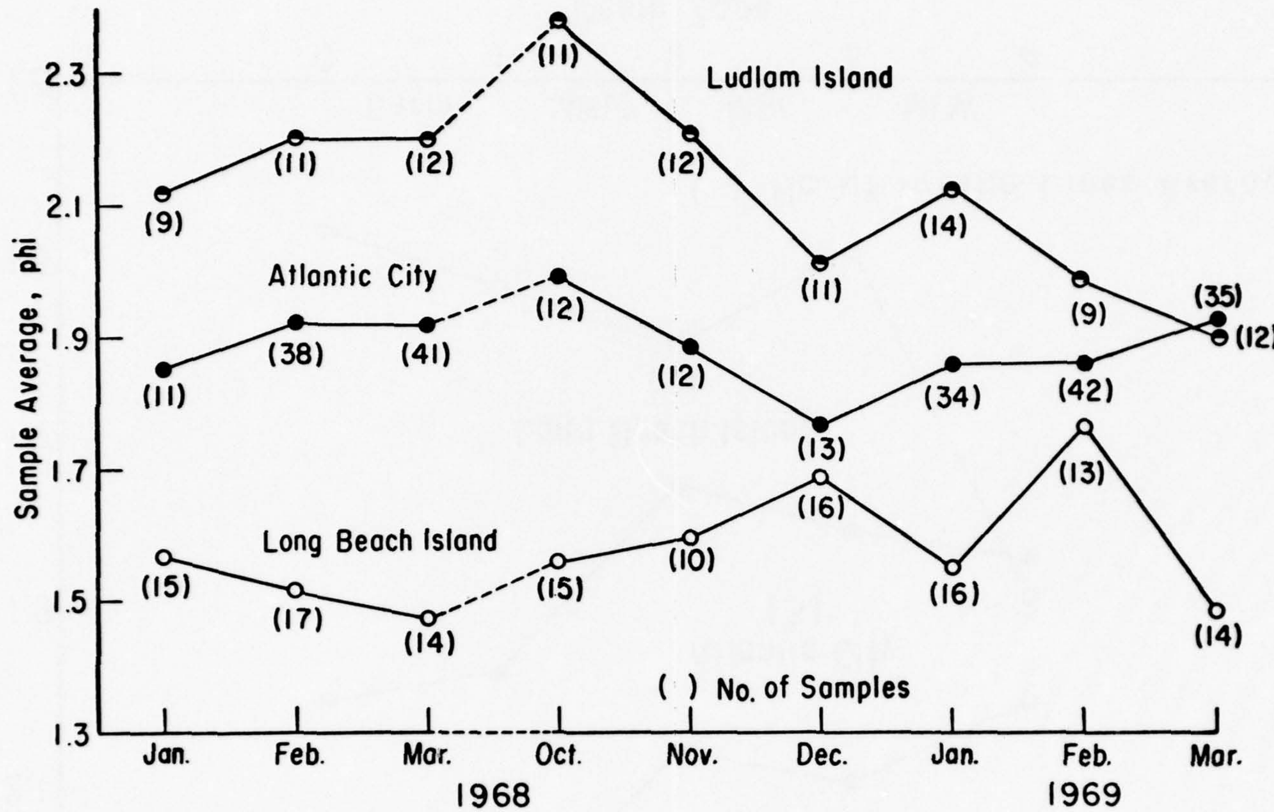

Figure 18. Monthly sand-size variation, sample set A.

for the intercept. The confidence intervals for the expected value of y_o given a certain x_o, $y_o = 0.84x_o - 0.06$, are:

$$[y_o + (0.268) \sqrt{0.034 + (x_o - 1.85)^2/4.543}]_{95\%}$$

$$[y_o + (0.222) \sqrt{0.034 + (x_o - 1.85)^2/4.543}]_{90\%}$$

The visual fit (Fig. 14) is a good approximation to the linear regression curve for RSA means between 1 and 2 phi (0.5 and 0.25 millimeter) which includes the values of the most frequently occurring RSA means in this study.

One possible explanation for the RSA giving a consistently coarser mean determination than the dry sieve analysis is the fluid mechanics effect of other particles of the sample on the fall velocity of an individual particle in the sample. Cook (1969, p. 781) suggested that smaller particles falling in a grain-size mixture are entrained by the larger particles, and therefore they may experience an increase of velocity by as much as 15 percent over their normal fall velocities. This would cause a sample to settle at a faster rate than predicted by the hydraulic characteristics of the individual grain. The RSA would then interpret the increased velocity as an increase in the concentration of larger particles, thus giving a mean which would be coarser than that determined by dry sieve methods. This explanation is effectively the same as that of Sanford (1970) who noted that a vertical turbidity current develops in the RSA settling tube, resulting in a sedimentation diameter which is consistently coarser than the equivalent sieve diameter. For coarse particles the effect may be just the opposite. The linear regression curve in Figure 14 and the studies by CERC (C. Judge, geologist, personal communication, November 1976) indicate that for coarser samples the RSA mean may be finer than the dry sieve mean. In addition, turbulence may affect the fall velocity of particles under some conditions.

There has been increased interest in this problem by workers in fluid mechanics. Further study should lead to a better interpretation of the sizes obtained from fall velocity measurements in equipment such as the RSA.

6. McMaster's Procedure.

There were some differences between McMaster's (1954) analysis procedure and CERC's analysis procedure; however, the effects of these differences have been minimized where possible in the following ways. The most important difference was in sampling method. At each sample site, McMaster collected three 6-inch (15 centimeters) core samples from positions spaced 15 feet (4.5 meters) apart along the high tide line. The top layer of sand was scraped off and the three samples were combined in one container and subsequently considered as one sample. Since CERC's samples are grab samples, the surface layer is included and the samples did not penetrate

as deeply into the beach. This difference is partly compensated for by the fact that CERC sampled a few times a month which should have the same effect as sampling a few layers at one time.

Since McMaster lists quartile-size fraction of each sample, the sample mean of his samples was probably calculated using:

$$Mn_{\phi} = (\phi_{25} + \phi_{50} + \phi_{75})/3 \quad , \tag{5}$$

instead of the five percentile mean (Fig. 12) used to compute CERC's sample means. Equation (5) has a statistical efficiency of about 88 percent (McCammon, 1962) while five percentile mean has an efficiency of 93 percent, so the error due to the method of calculation is probably not significant for these data.

McMaster wet-sieved his samples to remove any size fraction less than 0.053 millimeter; the CERC samples were not wet-sieved. However, analysis of CERC's data showed that only one dry sieve sample had a significant frequency percent (0.5 percent) finer than 0.064 millimeter, but none of the RSA samples gave zero percent for this size class.

Another difference was that McMaster also sieved for gravel, but only two of his samples taken from the same area considered in CERC's study had a recordable gravel frequency percent. In these two cases, the gravel content was 0.1 and 0.4 percent and these percentages could not significantly affect the quartile measurements used to characterize the size of his samples. A final minor difference is that McMaster used 0.5-phi sieve intervals which included 0.25, 0.75, etc.; CERC used 0.5-phi intervals which included 0.00, 0.50, etc. Both McMaster and CERC used the retaining sieve definition of size.

7. Sample Average and Profile Average.

To determine trends in the data, it is useful to deal with averages. Since each sample mean is identified by the three space coordinates and the time of sample collection (Apps. A and B of Ramsey and Galvin, 1971), there are a number of possible ways to average the data. In this report, sample means are segregated by profile line, position on profile, or month, and then averaged as "sample averages" or "profile averages". A sample average is obtained by adding sample means and dividing by the number of samples. A profile average is the average of a collection of sample averages, in the case where each sample average is from a different profile line. In effect, sample averages are weighted by the number of samples in the collection, and profile averages are weighted by the number of profiles in the collection.

To summarize the definitions used here, a *sample mean* is the mean of the size distribution of a single sand sample. A *sample average* is an average of selected sample means at one locality or one profile. A *profile*

average is an average of sample averages, each sample average representing conditions at a different profile line. For sample set A, the sample mean is the value obtained from equation (2), but for sample set B, the sample mean is the median given by the improved RSA program. For all practical purposes, the mean and the median of sand samples in this study are identical.

III. RESULTS

1. Sand-Size Distribution.

Tables 2 and 3 summarize the sample means of sample set A, with sample averages and profile averages given by profile line, elevation, and month of sample collection. Tables 4 and 5 are similar summaries for the RSA means of sample set B. Table 6 compares McMaster's (1954) results with results from sample set A for both the sample averages of the RSA means and the sample averages of sample means.

Figures 15 to 18 are plots of sample set A only (data from Tables 2 and 3). Sample averages are plotted against relative profile location in Figure 15 to illustrate the geographic distribution of mean sand size on southern New Jersey beaches. The distribution of mean size with elevation is illustrated first in Figure 16 as sample averages and then in Figure 17 as profile averages. Finally, the variation of mean sand size with time is shown in Figure 18 as sample averages by month.

2. Sample Mean versus Slope.

The sample means of all samples whose elevation was less than MHW are plotted against the slope of the sample site in Figure 19. The slopes were calculated from the survey data by the CERC computer program PRSEG. The solid line in Figure 19 is equivalent to the New Jersey-North Carolina curve on Figure 4-33 of the Shore Protection Manual (U.S. Army, Corps of Engineers, Coastal Engineering Research Center, 1975).

IV. DISCUSSION OF SAMPLE SET A

1. Magnitude of Size Variation.

The range of variation in mean sand size by profile, at the three localities studied, is from 1.55 phi (0.34 millimeter) at profile line 12 on Long Beach Island to 2.30 phi (0.20 millimeter) at profile line 10 on Ludlam Island (Fig. 15). The size difference between 0.20 and 0.34 millimeter has a coastal engineering significance in its effect on beach shape, slope, and width. Fall velocity of 0.34-millimeter sand is double that of 0.20-millimeter sand (U.S. Army, Corps of Engineers, Coastal Engineering Research Center, 1975, p. 4-84) which can result in the finer sand having a barred profile and the coarser sand having a profile with a prominent berm (U.S. Army, Corps of Engineers, Coastal Engineering Research Center, 1975, p. 4-81). According to Bascom (1951), 0.34-millimeter sand

Table 2. Average size by locality, profile line, and position on profile (sample set A).[1]

Locality	Profile line	Type of average	By locality	By profile line	By position on profile: Berm	Berm to MHW	MHW to MSL	MSL to MLW	Below MLW
Long Beach Island	3	Sample		1.65(32)[2]	1.43(7)	1.64(10)	1.76(2)	1.70(11)	2.01(2)
	12			1.55(32)	1.43(11)	1.49(6)	1.63(6)	1.41(3)	1.81(6)
	17			1.56(30)	1.53(10)	1.43(6)	1.49(4)	1.30(3)	1.87(7)
	19			1.56(36)	1.44(8)	1.55(8)	1.53(8)	1.55(7)	1.83(5)
		Sample	1.58(130)		1.46(36)	1.54(30)	1.58(20)	1.57(24)	1.86(20)
		Profile	1.58		1.46	1.53	1.60	1.49	1.88
Atlantic City	2	Sample		1.57(71)	1.66(12)	1.82(12)	1.57(9)	1.49(17)	1.43(21)
	4			2.00(85)	2.20(24)	2.07(20)	1.86(11)	1.88(14)	1.85(16)
	6			2.12(83)	2.24(25)	2.01(16)	1.85(12)	2.06(10)	2.24(20)
		Sample	1.91(239)		2.11(61)	1.99(48)	1.77(32)	1.76(41)	1.83(57)
		Profile	1.90		2.00	1.97	1.76	1.81	1.84
Ludlam Island	4	Sample		2.08(33)	2.03(2)	2.20(12)	2.10(7)	1.89(7)	2.06(5)
	10			2.30(33)	2.33(6)	2.41(9)	2.06(7)	2.28(4)	2.37(7)
	17			2.05(34)	2.29(5)	2.24(8)	2.02(5)	2.07(10)	1.60(6)
		Sample	2.14(100)		2.27(13)	2.28(29)	2.06(19)	2.05(21)	2.03(18)
		Profile	2.14		2.22	2.28	2.06	2.08	2.01

[1]All averages in phi units.
[2]Number in parenthesis is number of sample means in sample average.

Table 3. Sample averages by month (sample set A).[1]

Locality	Mo and yr	Average	Position on profile				
			Berm	Berm to MHW	MHW to MSL	MSL to MLW	Below MSL
Long Beach Island	Jan. 1968	1.57(15)[2]	1.47(6)	1.45(2)	1.61(2)	1.34(2)	1.99(3)
	Feb.	1.52(17)	1.37(3)	1.50(7)	1.44(2)	1.40(2)	1.84(3)
	Mar.	1.48(14)	1.48(6)	-------	1.60(2)	1.21(2)	1.57(4)
	Oct.	1.56(15)	1.34(5)	1.42(3)	1.77(3)	1.46(1)	1.88(3)
	Nov.	1.59(10)	1.57(2)	1.65(4)	-------	1.55(4)	-------
	Dec.	1.68(16)	1.53(5)	1.57(3)	1.73(2)	1.60(3)	2.10(3)
	Jan. 1969	1.55(16)	1.50(5)	1.68(3)	1.18(3)	1.83(3)	1.61(2)
	Feb.	1.77(13)	1.36(1)	1.54(4)	1.78(4)	2.10(2)	2.10(2)
	Mar.	1.48(14)	1.43(3)	1.54(4)	1.36(2)	1.51(5)	-------
Atlantic City	Jan. 1968	1.85(11)	2.27(2)	1.98(3)	1.72(2)	1.61(3)	1.62(1)
	Feb.	1.93(38)	2.14(9)	2.03(11)	1.79(8)	1.83(2)	1.70(8)
	Mar.	1.92(41)	2.20(10)	2.04(10)	1.75(8)	1.63(6)	1.79(7)
	Oct.	1.98(12)	1.92(4)	1.75(1)	2.06(2)	1.97(2)	2.09(3)
	Nov.	1.87(12)	2.08(4)	1.91(1)	1.21(1)	1.83(3)	1.82(3)
	Dec.	1.77(13)	1.89(2)	1.83(3)	1.48(3)	1.80(2)	1.89(3)
	Jan. 1969	1.86(34)	2.19(6)	1.82(9)	1.86(2)	1.67(9)	1.88(8)
	Feb.	1.86(42)	2.00(12)	2.05(6)	1.69(6)	1.67(7)	1.81(11)
	Mar.	1.94(35)	2.08(12)	2.10(3)	1.58(1)	1.89(7)	1.79(13)
Ludlam Island	Jan. 1968	2.12(9)	1.97(2)	2.45(2)	2.05(2)	2.06(3)	-------
	Feb.	2.20(11)	2.33(2)	2.17(3)	2.31(1)	2.07(4)	2.46(1)
	Mar.	2.20(12)	1.97(2)	2.47(3)	2.16(2)	2.10(1)	2.16(4)
	Oct.	2.38(11)	2.49(3)	2.48(3)	2.34(3)	2.13(2)	-------
	Nov.	2.21(12)	-------	2.40(4)	2.15(4)	1.91(2)	2.26(2)
	Dec.	2.02(11)	2.30(2)	2.20(3)	2.11(2)	1.84(2)	1.55(2)
	Jan. 1969	2.13(14)	2.17(2)	2.32(4)	1.85(2)	2.14(3)	2.03(3)
	Feb.	2.01(9)	-------	2.11(4)	1.89(1)	1.93(2)	1.93(2)
	Mar.	1.88(12)	-------	2.00(3)	1.54(2)	1.96(3)	1.90(4)

[1]All sample averages in phi units.
[2]Number in parenthesis is number of sample means in sample average.

Table 4. Average size by locality, profile line, and position on profile (sample set B).[1]

Locality	Profile line	Type of average	By locality	By profile line	By position on profile				
					Berm	Berm to MHW	MHW to MSL	MSL to MLW	Below MSL
Island Beach	1	Sample		1.28(26)[2]	1.24(12)	1.39(5)	1.13(5)	1.43(4)	-------
	3	Sample		1.43(36)	1.33(4)	1.43(17)	1.36(9)	1.58(4)	1.66(2)
		Sample	1.37(62)		1.26(16)	1.42(22)	1.28(14)	1.51(8)	1.66(2)
		Profile	1.36						
				1.46(21)	1.40(7)	1.54(7)	1.62(2)	1.36(5)	-------
Long Beach Island	13	Sample		1.49(13)	1.37(4)	1.62(5)	1.62(2)	1.26(2)	-------
	33			1.41(8)	1.44(3)	1.33(2)	-------	1.43(3)	-------
	16			1.59(24)	1.43(2)	1.57(10)	1.61(5)	1.73(6)	1.12(1)
		Sample	1.53(45)		1.41(9)	1.56(17)	1.61(7)	1.56(11)	1.12(1)
		Profile	1.50						
Brigantine	1	Sample		2.15(6)	-------	2.24(3)	2.07(1)	2.06(2)	-------
	2			2.25(6)	-------	2.15(3)	2.40(1)	2.13(1)	2.55(1)
		Sample	2.20(12)		-------	2.20(6)	2.36(2)	2.08(3)	2.55(1)
		Profile	2.20						
Absecon Island	5	Sample		1.93(42)	1.98(20)	1.93(5)	2.02(7)	1.76(10)	-------
	7			2.08(36)	1.75(1)	2.11(16)	2.08(5)	2.11(13)	1.70(1)
					1.97(21)	2.07(21)	2.04(12)	1.96(23)	1.70(1)
	4			2.07(1)	-------	-------	2.07(1)	-------	-------
	3			1.98(1)	1.98(1)	-------	-------	-------	-------
	6			2.11(1)	-------	-------	2.11(1)	-------	-------
		Sample	2.00(81)						
		Profile	2.03						
Ludlam Island	5	Sample		2.09(43)	2.19(5)	2.15(19)	2.31(1)	1.93(12)	2.02(6)
	18			2.09(37)	2.10(5)	2.14(13)	2.05(4)	1.98(11)	2.26(4)
					2.14(10)	2.14(32)	2.10(5)	1.95(23)	2.12(10)
		Sample	2.09(80)						
		Profile	2.09						

[1]All sample averages in phi units.
[2]Number in parenthesis is number of sample means in sample average.

Table 5. Sample averages by month (sample set B).[1]

Locality	Mo and yr	Average
Island Beach	Jan. 72, 73	1.44(6)[2]
	Feb. 72, 73	1.34(7)
	Mar. 72, 73	1.38(8)
	Apr. 72, 73	1.38(12)
	May 72	1.35(4)
	June 73	1.36(4)
	Aug. 72	1.37(5)
	Oct. 72	1.41(7)
	Dec. 72	1.46(7)
Long Beach Island	Jan. 69, 71, 72	1.52(8)
	Feb. 72, 73	1.55(9)
	Mar. 69, 71, 72, 73	1.42(10)
	Apr. 72, 73	1.55(10)
	May 72	1.45(2)
	June 73	1.64(2)
	July 71	1.32(2)
	Aug. 71, 72	1.54(8)
	Oct. 71, 72	1.58(4)
	Nov. 72	1.64(2)
	Dec. 68, 71, 72	1.44(7)
Absecon Island	Jan. 69, 72	1.96(10)
	Feb. 72, 73	1.98(12)
	Mar. 71, 72, 73	1.94(14)
	Apr. 72, 73	1.94(12)
	May 72, 73	1.99(8)
	June 73	1.76(4)
	Aug. 71, 72	2.16(8)
	Oct. 72	2.03(6)
	Dec. 72	1.99(7)
Ludlam Island	Jan. 69, 72, 73	2.09(9)
	Feb. 72, 73	1.96(12)
	Mar. 69, 70, 71, 72, 73	2.12(18)
	Apr. 72, 73	2.04(12)
	May 73	2.07(7)
	June 73	2.18(2)
	Aug. 71, 72, 75	2.17(8)
	Oct. 72	2.19(3)
	Nov. 70	2.31(1)
	Dec. 71, 72	2.07(8)

[1]All sample averages in phi units.
[2]Number in parenthesis is number of sample means in sample average.

Table 6. Comparison of CERC's size data with McMaster's size data (sample set A).[1]

Source	Sample average		
	Long Beach Island	Atlantic City	Ludlam Island
CERC (RSA mean)	1.20(26)[2]	1.65(48)	1.95(29)
CERC (Sample mean)	1.53(26)	1.98(48)	2.28(29)
McMaster (1954)	1.59(19)	2.52(9)	2.60(8)

[1]Size in phi units.
[2]Number in parenthesis is number of sample means in sample average.

NOTE.--CERC samples from berm to MHW profile segment, collected in fall, winter, and spring. McMaster samples from most recent high tide line, collected in summer.

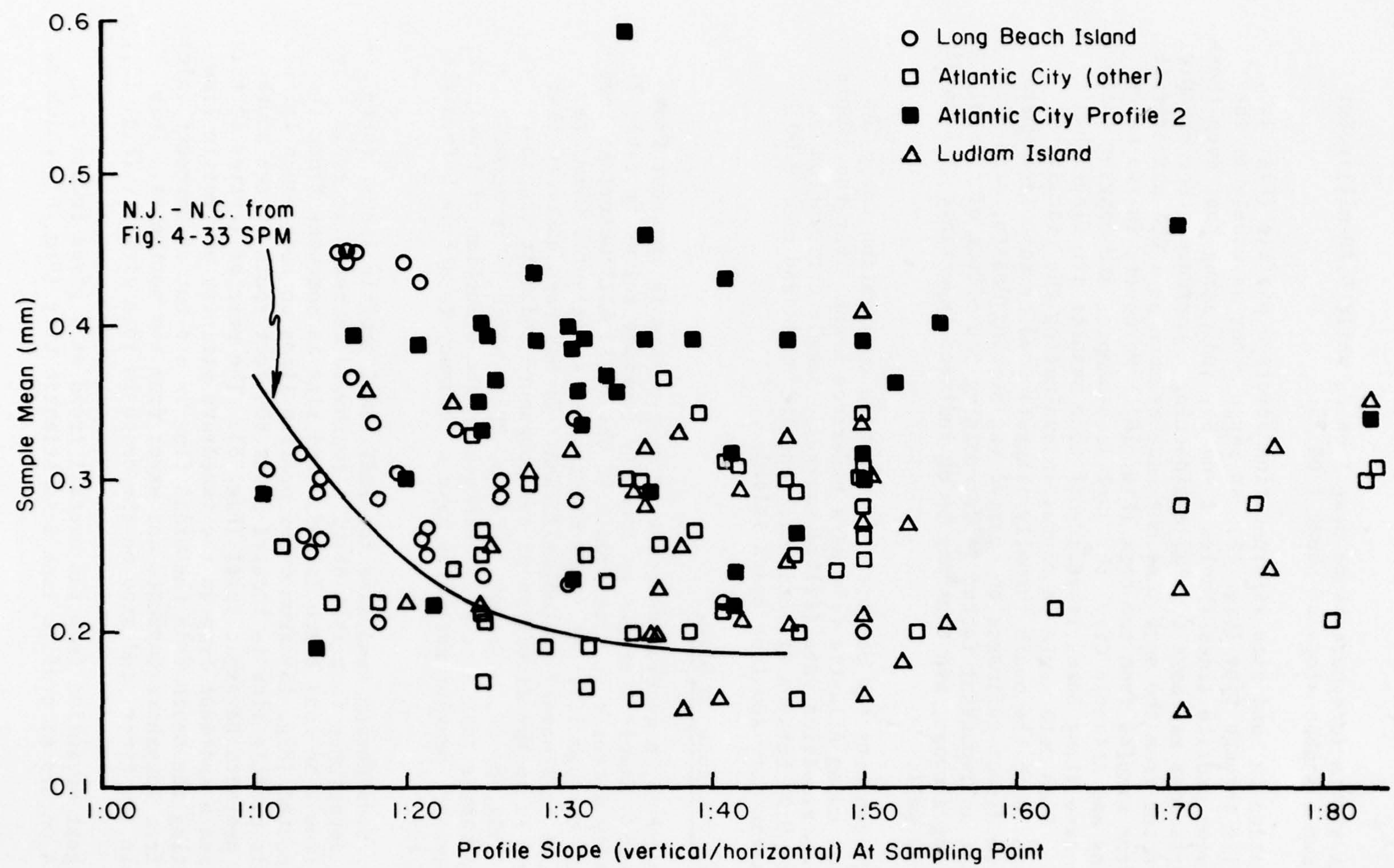

Figure 19. Sand size-beach slope relation for New Jersey sand samples (sample set A).

should have a stable foreshore slope near 1 on 25 while 0.20-millimeter sand would have a stable slope of about 1 on 75.

The variation in sand size with position across a profile (Fig. 16), or at a profile through time (Fig. 18) can range about as widely as the extremes between profile lines (Tables 2 and 3), indicating that even these sand-size variations may have coastal engineering importance. For example, samples collected from the surf zone may have as much as a 0.4-phi average difference from samples from the berm (Fig. 16). Moreover, in two cases (Ludlam Island and Atlantic City) the surf zone samples are coarser while in the other case (Long Beach Island) surf zone samples are finer than berm samples. Such data would be useful in evaluating the practice of bulldozing sand onto the beach (usually illegal) used by some landowners. In addition to direct influence on coastal engineering design, sand-size variations are an important factor in determining the effect of coastal processes along a coast, and thus may be of indirect importance to coastal engineering as well.

Figure 20 exhibits the positive and negative correlation among the three beaches, using Atlantic City as a reference beach. For the sample average versus elevation data (filled squares), sample correlation coefficients were 0.92 between Atlantic City and Ludlam Island and -0.50 between Atlantic City and Long Beach Island.

2. Southward Decrease in Size.

From Figure 15, a general decrease in sample size is apparent from north to south. Sample averages by locality (average column in Table 2) show an orderly decrease in size from 1.58 phi (0.33 millimeter) at Long Beach Island, through 1.91 phi (0.27 millimeter) at Atlantic City, to 2.14 phi (0.23 millimeter) at Ludlam Island. It has been observed that this decrease is in the direction of net longshore sediment transport (MacCarthy, 1931, p. 37; McMaster, 1954, p. 207), which is in accordance with the hypothesis that size will decrease in the direction of transport, since the coarser, heavier particles have a tendency to settle before the finer particles.

However, considering sand size for individual profile lines, there are significant departures from this overall southward decrease in grain size. At profile line 3 on Long Beach Island, sand size is somewhat finer than would be expected (Fig. 15) from other profile lines on Long Beach Island. However, this profile line is located about 600 feet south of the south jetty which protects Barnegat Inlet (Fig. 3). The pair of jetties at this inlet may form a sediment trap in the immediate vicinity of profile line 3 by protecting the beach from the tidal flow in and out of Barnegat Inlet, as well as from longshore currents and waves from the northeast. This would explain the finer sand size on the beach in this vicinity (Fig. 15).

The largest deviation from the overall trend at a given locality in sample set A occurs at profile line 2 in Atlantic City (Fig. 6), which is

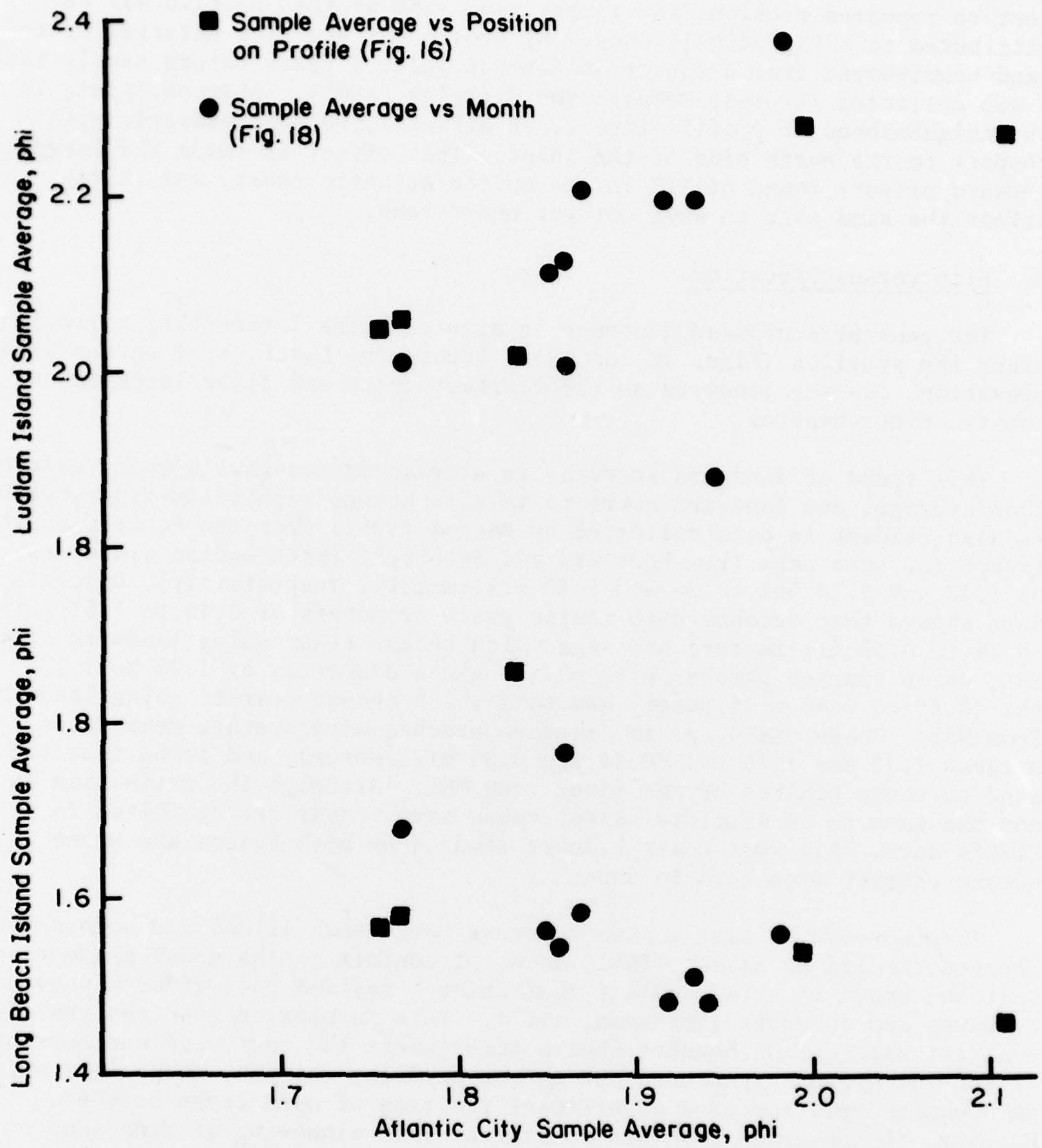

Figure 20. Positive (Atlantic City - Ludlam Island) and negative (Atlantic City - Long Beach Island) correlation of sand-size variation, sample set A.

located about 1,200 feet south of Absecon Inlet. This site has been subject to repeated erosion; the larger sand size at this profile may be attributed to a lag deposit caused by erosion of the fine material or to sand nourishment from a source in Absecon Inlet 5 years before sample set A was collected (Everts, DeWall, and Czerniak, 1975). Absecon Inlet, in the neighborhood of profile line 2, if offset 2,900 feet seaward, with respect to the north side of the inlet. This offset is among the largest seaward offsets found at 127 inlets on the Atlantic coast, and it may affect the sand size in ways not yet understood.

3. Size versus Elevation.

The general southward decrease in size contains interesting variations along the profiles (Figs. 16 and 17). Across the beach, size varies with elevation, coarser landward on the coarsest beach and finer landward on the two finer beaches.

This trend of landward increase in size across beaches already coarser than average, and landward decrease in size across relatively finer beaches is also evident in data collected by Bascom (1951) from the Pacific coast. Except for some data from Fort Ord and Seabright (with median diameters of 1.47 and 1.74 phi (0.36 and 0.30 millimeter), respectively), Bascom's data showed that beaches with median grain diameters of 2.40 to 1.51 phi (0.19 to 0.35 millimeter) had sand which became finer going landward from MSL, while coarser beaches with median grain diameters of 1.25 to 1.12 phi (0.42 to 0.46 millimeter) had sand which became coarser going landward from MSL. Duane (1970, p. 15) studied beaches with average mean sizes between 1.30 and 1.76 phi (0.41 and 0.30 millimeter), and found that the sand on these beaches became finer from MSL. Although the grain size is not the same in an absolute sense, these same trends are exhibited in CERC's data. All west coast beaches studied by both Bascom and Duane became coarser from berm to dune.

The increase in size landward across Long Beach Island and across the beaches studied by Bascom (1951) does not conform to the usual assumption that the beach is a lag deposit containing a residue left after winnowing by waves and currents (Friedman, 1967). This assumption requires that the coarsest material on beaches should occur where the most wave and current action is, presumably around MLW on the profile; whereas, these data suggest an opposite relation on a significant fraction of open ocean beaches. However, the observed data are consistent with winnowing of fine sand on the subaerial beach by wind action.

4. Size versus Month.

The monthly distribution of sand sizes at the three localities is shown in Figure 18. Here, as in the variation across the profile (Figs. 16 and 17), Atlantic City and Ludlam Island vary in the same way, and Long Beach Island varies in the opposite sense. Figure 18 exhibits the correlation among the three beaches for sample average versus month data (circles).

Sample correlation coefficients computed for the open circle data on Figure 18 gave 0.45 between Atlantic City and Ludlam Island and -0.60 between Atlantic City and Long Beach Island. There is a general decrease in sample mean between the samples collected in March 1968 and those collected in October 1968, but there is no obvious annual cycle.

Monthly changes seem greater at Ludlam Island. The maximum variation in sample mean during 1 year for any one beach was 0.52 phi (0.083 millimeter) (October 1968 to March 1969 for Ludlam Island) and the maximum variation over 1 month for any one beach was 0.29 phi (0.065 millimeter) (February to March 1969 for Long Beach Island). This 1-month variation also happens to be the maximum variation for 1 year on Long Beach Island.

Data collected between 1954 and 1965 (Galvin, et al., 1969) show that the surf on the north Atlantic coast is least active during the months of June and July and most active from August to March. Unfortunately, no sand samples were collected for sample set A from April through September. Also, insufficient 1968-69 wave data from the sample area were available to make any correlation between sample mean and wave activity at the time of sample collection.

5. Comparison with McMaster's Data.

McMaster (1954) collected samples only along the latest high tide line on the beach and, consequently, most of his samples probably come from the berm to MHW segment of the profile, using the definitions which appear in Figure 9. Therefore, to make CERC's data comparable to his, only those samples taken from this berm to MHW segment were used to compute CERC's RSA and sample means in Table 4.

Table 4 shows that CERC's sample means are only slightly coarser than McMaster's for Long Beach Island, but for the other two localities CERC's data show a considerably coarser mean. It should be noted that McMaster collected his samples during late June and early August when there is usually less surf activity and, perhaps, finer particles on the beach. Since sample set A lacks samples collected during the summer months, such a seasonal effect may be the reason for CERC's data showing a coarser mean. Figure 18 shows month-to-month variations, even without summer samples, as great as 0.065 millimeter in CERC data, which is on the same order as the maximum difference (0.079 millimeter) between CERC and McMaster's data.

6. Sample Mean versus Slope.

Many investigators have found that slope of the beach face is related to sand size (Bascom, 1951; U.S. Army, Corps of Engineers, Coastal Engineering Research Center, 1975, p. 4-86). For New Jersey beaches, McMaster (1954) found that "coarse and medium sands are restricted to gentle and moderately inclined foreshores and fine sands occur on nearly flat shores;" Urban and Galvin (1969) noted that slope of the beach face and general

sand size decreased from north to south at the three localities in this study.

Figure 19 indicates that this trend is not clearly evident on the basis of individual sample means, and at profile line 2 of Atlantic City, the trend appears to be opposite of the expected. However, when overall averages are taken, the mean slope sand-size pairs for the three localities are: Long Beach, 0.052 and 0.31 millimeter; Atlantic City, 0.028 and 0.28 millimeter; and Ludlam Island, 0.022 and 0.24 millimeter. These averages are well within the scatter of data on this relation, but generally fall below the slope versus grain-size curve for west coast conditions rather than the New Jersey conditions (U.S. Army, Corps of Engineers, Coastal Engineering Research Center, 1975, p. 4-86). In part, the lack of a clearer relation between size and slope may be due to the relatively small range of sizes in these samples.

V. DISCUSSION OF SAMPLE SET B

1. Questions.

The reason for collecting sample set B was to answer the following questions evolved in the analysis of sample set A:

a. What is the longshore variation in sand size outside the profile lines sampled in sample set A?

b. Is the seaward decrease in size across Long Beach Island (which is a highly developed beach with many groins) found immediately to the north on Island Beach (which is a state park without structures)?

c. What happens to the sand size in the summer months, for which in sample set A lacks data?

2. Longshore Variation.

Figure 21 shows longshore variation in size for sample set B, in a manner similar to Figure 15 for sample set A. The additional localities in sample set B suggest that instead of a gradual southward decrease in sand size along the New Jersey coast, there is a discontinuity in size between Long Beach Island and Brigantine, i.e., near Little Egg Inlet. This discontinuity in sand size matches a discontinuity in heavy minerals at Little Egg Inlet found by McMaster (1954).

3. Seaward Variation.

As shown by the data on Figure 22, the new data from Island Beach confirm the trend found at neighboring Long Beach Island (Figs. 16 and 17)--sand size gets finer toward the surf zone. However, the tendency of sample set A to get coarser in the seaward direction on Atlantic City and Ludlam Island beaches is not as well supported by sample set B, although

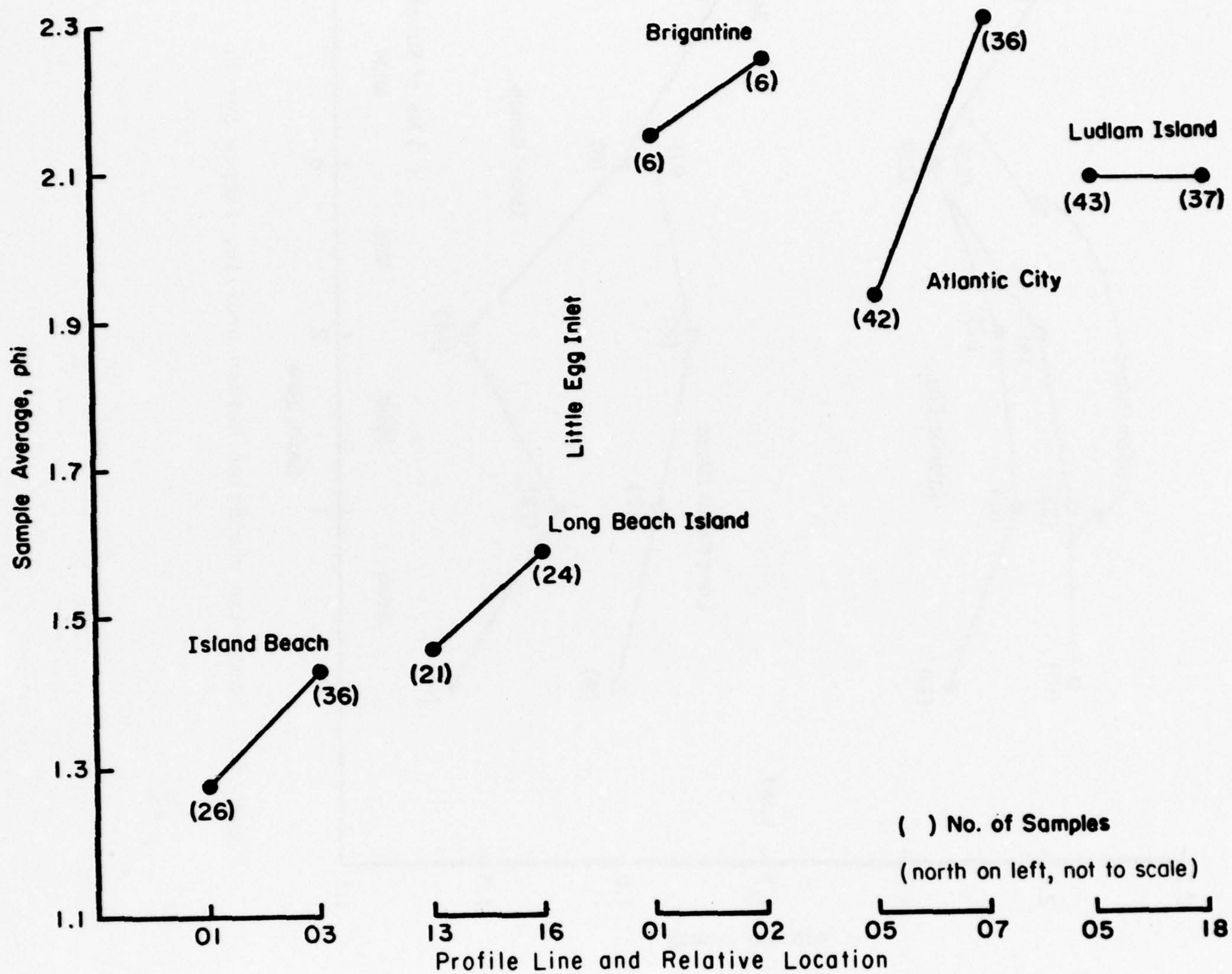

Figure 21. Decrease in sand size south of Little Egg Inlet, sample set B.

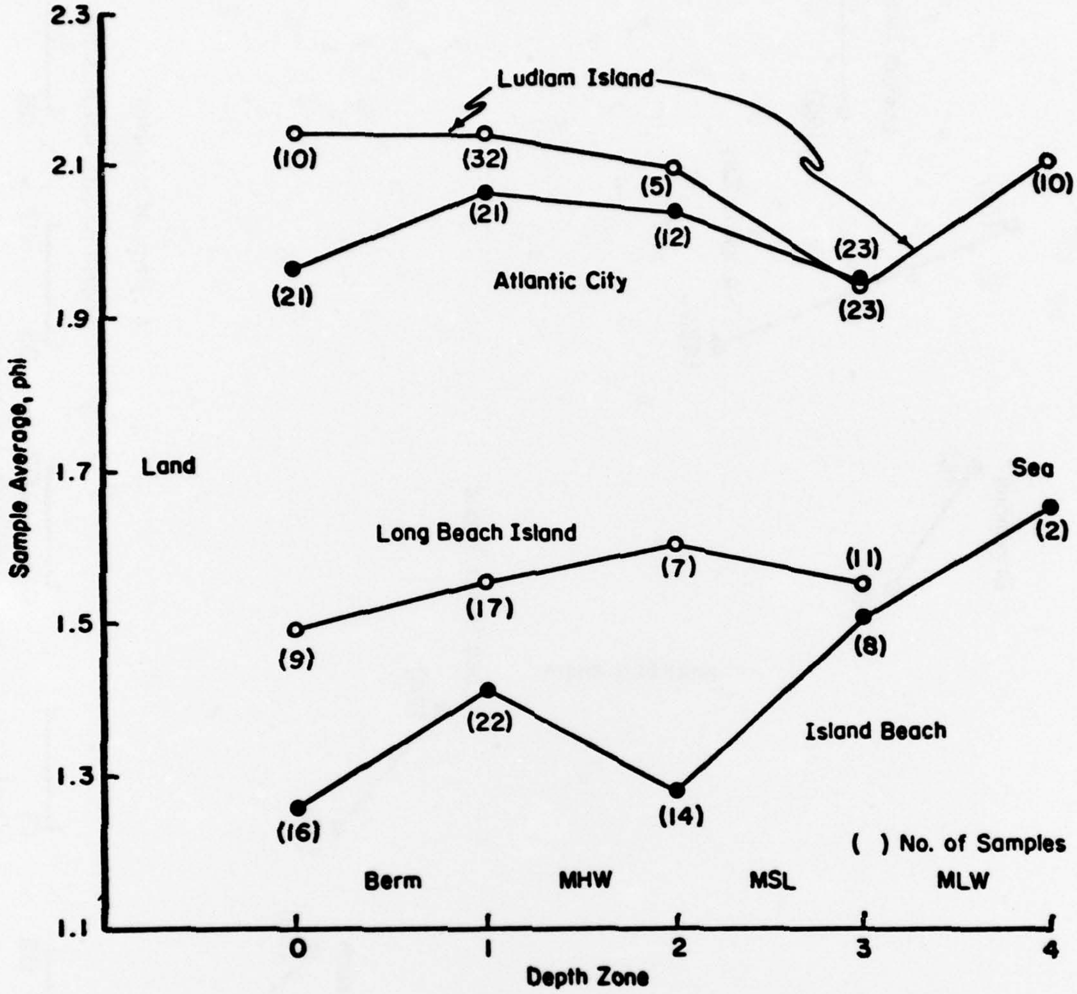

Figure 22. Sand-size variation across profile, sample set B.

the mean trend for sample set B from Atlantic City and Ludlam Island is toward coarser values on the seaward end.

4. Monthly Variation.

The size variation by month at Island Beach, Long Beach Island, Atlantic City, and Ludlam Island is shown in Figure 23. Sample set B has data for May, June, July, and August to help fill the gap in Figure 18 for sample set A.

Although a clearly defined annual cycle in Figure 23 is not noticeable, the data suggest that sand tends to get finer on the beaches in late summer and fall. For the four localities (Fig. 23), the months with the finest sand are:

Island Beach	October, December, and January
Long Beach Island	June, August, October, and November
Atlantic City	August, October, and December
Ludlam Island	June, August, October, and November

For sample set A, which lacks data between March and October, the finest sand occurred in October on two of the three beaches sampled.

McMaster (1954) sampled in the summer and CERC mainly in the winter. Since Figure 23 suggests that the summer usually has finer sand on the beaches, this seasonal difference may account for some of the difference between CERC's and McMaster's data shown in Table 6.

VI. CONCLUSIONS

1. Sand Size.

Conclusions from this study are based mainly on the data in sample set A, supplemented where possible by sample set B. The basic data for these conclusions are largely contained in the appendixes of Ramsey and Galvin (1971), and summarized in Tables 1 to 6 and Figures 15 to 23 of this report.

a. The crude sampling methods used to collect the samples give surprisingly consistent results that show trends in location, position on profile, and month of collection.

b. The size analysis procedure used with the CERC RSA indicates sample means that are consistent among themselves. For sample set A, 30 RSA means average about 0.33 phi units coarser than dry sieve means measured from the same samples (eq. (2) and Fig. 14). (At the time of analysis of sample set B, the RSA program had been modified, so sample set A was modified by equation (2) and sample set B was not.)

c. For sample set A, sand size, as given by sample averages at a profile line, ranges from 0.20 to 0.34 millimeter (2.30 to 1.55 phi) at profile

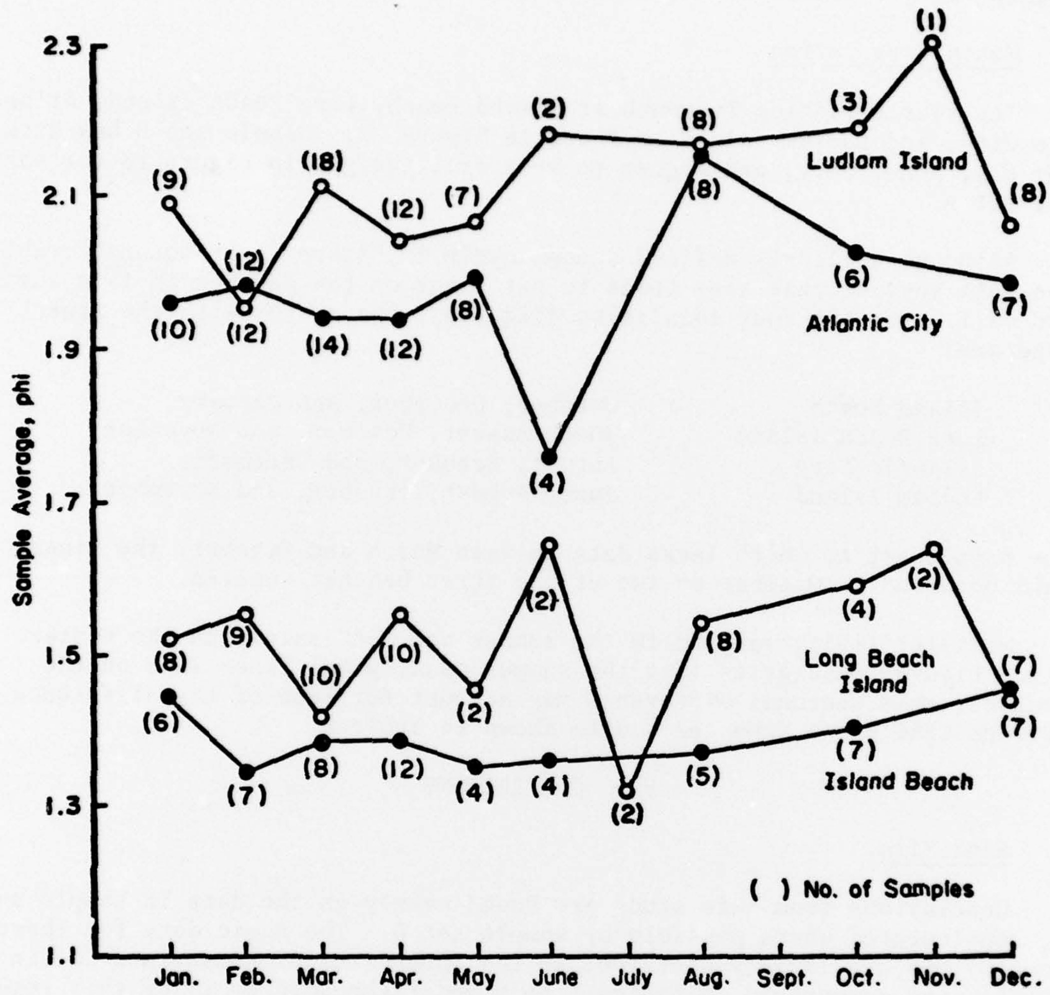

Figure 23. Monthly sand-size variations, sample set B.

line 10 of Ludlam Island (finest) and profile line 12 of Long Beach Island (coarsest). Variations with time at a profile line and with position across a profile are nearly as great as between profiles (Tables 2 and 3).

d. Sand size tends to decrease southward from Island Beach to Townsends Inlet in southern New Jersey. Evidence from sample set B suggests that there is a discontinuity in size at Little Egg Inlet between Long Beach Island and Brigantine. McMaster (1954) found a discontinuity in heavy mineral occurrence across Little Egg Inlet, along with a relatively rapid southward decrease in sand size.

e. Sand size tends to get finer landward across profiles on Atlantic City and Ludlam Island, but it tends to get coarser landward across the profiles on Long Beach Island and Island Beach. Both sample averages (Fig. 16) and profile averages (Fig. 17) show this same trend, although sample averages show a somewhat smoother variation, and sample set B shows less pronounced trends at Atlantic City and Ludlam Island.

f. For the data of sample set A, monthly variation of sand size at the three localities studied does not suggest an annual cycle in the 9 months sampled between January 1968 and March 1969, inclusive (Fig. 18). However, monthly variation in sample set B suggests that sand size is finer during late summer and early fall on these beaches (Fig. 21), although a pronounced annual cycle is not evident.

g. Sample set A data suggest that size variation at Atlantic City is positively correlated with variation at Ludlam Island and negatively correlated with variation at Long Beach Island (Fig. 20). These correlations are found for size variation with both position on the profile (Fig. 16) and month (Fig. 18).

2. Coastal Engineering Applications.

a. The data in this report have a site specific use for coastal engineering design in the localities sampled. These data supplement information given in Table C-2 of U.S. Army Engineer District, Philadelphia (1974) and related studies. Such size data can be used, for example, with dimensionless falltime parameters to predict profile shape (U.S. Army, Corps of Engineers, Coastal Engineering Research Center, 1975, p. 4-81).

b. The size variation along and across the beaches, and with the month affects planning for beach fills on these shores. For example, Figure 16 indicates that size differences in the surf zone between localities are less than size differences on the berm between the same localities. This suggests that one size class of sand will be preferentially sorted toward the surf zone. Thus, finer-than-native sand may provide more protection than expected as a berm on beaches such as Atlantic City and Ludlam Island, but not on Long Beach Island. These size differences also suggest that greater longshore dispersion of beach fills will be obtained from sand whose size matches the surf zone samples rather than the berm samples.

c. Finally, the data on sand-size variation may improve understanding of the coastal processes acting on beach sand. For example, the sand size is relatively coarse on Island Beach and Long Beach Island, but relatively fine on Atlantic City and Ludlam Island, with evidence of a discontinuity in sand characteristics at Little Egg Inlet. This suggests further study to examine the source of sand thought to be transported in the longshore direction on these shores.

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